

**FISCAL YEAR 1985 DEPARTMENT OF ENERGY
AUTHORIZATION
(Transportation Programs)**

HEARINGS
BEFORE THE
SUBCOMMITTEE ON TRANSPORTATION,
AVIATION AND MATERIALS
OF THE
COMMITTEE ON
SCIENCE AND TECHNOLOGY
HOUSE OF REPRESENTATIVES
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FISCAL YEAR 1985 DEPARTMENT OF ENERGY AUTHORIZATION

(Transportation Programs)

TUESDAY, FEBRUARY 21, 1984

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SUBCOMMITTEE ON TRANSPORTATION,
AVIATION, AND MATERIALS,
Washington, D.C.

The subcommittee met, pursuant to notice, at 2:10 p.m., in room 2325, Rayburn House Office Building, Hon. Dan Glickman (chairman of the subcommittee) presiding.

Present: Representatives Glickman, Carney, Boehlert, and McCandless.

Mr. GLICKMAN. Good afternoon, everyone.

These hearings will focus on the portion of the Energy Department's budget which goes to transportation-related research and development. This is a critical area and one fact clearly confirms that: 61 percent of all petroleum used in this country goes to transportation. That is up from just 51 percent in 1973.

We continue to rely much too heavily on imported oil for our own good. That dependence on imported petroleum is particularly troubling when we hear, in fact today, of talk of U.S. ships headed again to the Straits of Hormuz to protect against disruption as a result of the continuing conflict between Iran and Iraq, a disruption of that vital oil supply lifeline. The net effect is another strain, another demand on our military forces.

There has been talk for years about the need for energy independence. It is generally agreed that it is a critical component of our Nation's security, but at the same time as we see the administration asking for large budget increases for the Pentagon, they have come to us again with a plan not to enhance in any way the core of the relatively small transportation R&D program which is, again, related to near over 60 percent of the energy that we use in this country that is imported energy from the Middle East.

We have a budget problem and we have to deal with it in the event of trying to achieve some fiscal sanity in this country, but we do have to look at the specific program areas and allocations within the Department of Energy to make sure that they are accurately funded.

The administration recommends a 23-percent reduction in DOE transportation R&D programs, at the same time as it more or less

holds nuclear R&D funding constant, even though nuclear energy aims at a very small sector of our energy use. The administration calls for wrapping up its alcohol fuel data base collection this year and pulling out of important R&D work on the transportation compatibility of this increasingly available fuel alternative; and the administration, which claims to recognize the importance of competition, calls for consolidating two gas turbine contracts into one. In addition, it calls for terminating the Stirling engine research program just 2 years before it was to finalize its work.

I recognize that we have to cope with budget realities but, as I have told my constituents in Kansas, I think a much better place to start than the President's budget is, so to speak, an across-the-board freeze. That is certainly the case in this area of the budget. Holding the line makes economic sense and strategic sense. Cutting these programs to the bone makes no sense in the long run, particularly if we find ourselves in a war in the Middle East.

Now I am looking at the budget request and I am happy to say that I do see some signs of improvement, however, from the stone-wall attitude of the past 3 years. No longer do we see mindless opposition to any and all Federal support for technology advancement in the automotive field. In fact, the Department seems to be behaving much more responsibly in providing for the future than it has in the past.

Now I would recognize my colleague from New York, Mr. Carney.

Mr. CARNEY. Thank you, Mr. Chairman.

Improving fuel efficiency and reducing our energy dependence is as important today as ever, so we can all support the goals of the DOE's transportation R&D program.

Unfortunately, the present supply of oil appears to be misleading some into thinking that the need for conservation has ended. Last year, after over 5 years of steadily declining oil imports, we began to increase those imports again. This is cause for concern, for as long as we continue to rely on others for our energy needs, we are still vulnerable.

However, it is not cause for alarm. I hope we can agree there is an equally pressing need to conserve our limited financial resources. We simply have to start being more discriminating in our support of R&D. We have to learn to distinguish between those programs which are essential for the well-being of the country and those which are merely beneficial, and perhaps even more for some than for others.

I think the budget that DOE has proposed for fiscal year 1985 represents a realistic compromise between what some of the subcommittee would like to see and what the Nation can realistically afford. Development of high temperature materials is a key element in the development of improving engine efficiency. This is reflected in the budget request for increased funding in that area. The importance of this technology is further recognized by the plan to continue funding for ceramic component testing by both contractors involved in the gas turbine engine program.

However, perhaps the time has come to reduce the Federal Government's participation in further proof of concept demonstrations. This is not meant to conclude that these concepts have no merit. It

simply is a question of funding priorities and private sector responsibilities. We have to make choices.

The testimony we will be hearing today should help us in making those choices. I join in welcoming Mr. Collins to this hearing, and I look forward to hearing his testimony on the fiscal year 1985 transportation budget, particularly the R&D section.

Thank you, Mr. Chairman.

Mr. GLICKMAN. Thank you, Mr. Carney.

Does anybody else in the committee have an opening statement?

Mr. McCANDLESS. No, Mr. Chairman.

Mr. GLICKMAN. If not, we will move right to you, Mr. Collins. It is a pleasure to have you here today, and we are most appreciative that you came down.

STATEMENT OF WILLIAM PATRICK COLLINS, UNDER SECRETARY AND ACTING ASSISTANT SECRETARY FOR CONSERVATION AND RENEWABLE ENERGY, U.S. DEPARTMENT OF ENERGY, ACCOMPANIED BY DONNA R. FITZPATRICK, PRINCIPAL DEPUTY ASSISTANT SECRETARY FOR CONSERVATION AND RENEWABLES; ALAN J. STREB, ACTING DEPUTY ASSISTANT SECRETARY FOR CONSERVATION; AND PAUL J. BROWN, ACTING DIRECTOR, OFFICE OF VEHICLE AND ENGINE RESEARCH AND DEVELOPMENT

Mr. COLLINS. Thank you, Mr. Chairman. I have a statement for the record. I would like to offer that statement, if I may, please.

Mr. GLICKMAN. Your entire statement will be put in the record.

Mr. COLLINS. First of all, I also would like to recognize Donna Fitzpatrick and Mr. Al Streb, the newly appointed principal deputy assistant secretary for conservation and renewable energy, and the acting deputy assistant secretary for conservation.

As you know, Mr. Chairman, when I assumed the position of Under Secretary this past August, the Secretary gave me a specific mandate to improve the Department's energy programs in conservation and renewable energy, and to be particularly conscious of the activities of the Congress and this committee in that sense. The position of Under Secretary has been refocused on this to underline the priority of this effort within the Department of Energy.

One of my first initiatives was the establishment of a thorough review of our ongoing and proposed programs to insure that adequate funding would be available, and adequate coverage was provided to a broad spectrum of technological options. The budget for the Department's energy conservation R&D program in transportation was developed in concert with the fourth national energy policy plan published in October, and fully supports the goals and strategies set forth in that document.

The overall goal of the national energy policy is to foster an adequate supply of energy at reasonable costs. The policy recognizes that adequate supply requires flexibility in the energy system, with no undue reliance on a single source of supply. The goal of reasonable costs suggests economic efficiency within the energy system. Of course, we seek to also minimize the Federal control and involvement in energy markets, while maintaining public health, safety, and environmental quality.

The fiscal year 1985 budget implements this strategy by supporting development of a mix of technologies that can contribute to the energy supply and end-use energy efficiency. In allocating our resources, we concentrated on applying Federal funds only where they are most effective, in basic and applied research where the potential payoff is high but which the private sector cannot be expected to pursue. Our fiscal year 1985 budget program funding of \$148 million for conservation research and development is almost equal to the fiscal year 1984 appropriation and more than twice the fiscal year 1984 request by the administration.

Of this amount, \$51 million is requested for the transportation program, \$10 million more than was requested in fiscal year 1984. The Department's transportation programs conduct R&D designed to improve energy efficiency in transportation and to develop new technologies which can serve as an alternative to those based exclusively on petroleum. We feel that this is a very important area for research since transportation's share, as you noted, of the U.S. petroleum consumption has increased from 51 percent to 61 percent in the last decade.

Of course, our program focuses on the highway because 76 percent of our petroleum use for transportation is in highway vehicles. The transportation program will continue to support the private sector efforts to improve the energy efficiency of vehicle systems, with particular emphasis on automotive gas turbines, research in adiabatic diesel technology and advanced batteries for electric and hybrid vehicles. The request also provides funds to complete construction of our high temperature materials laboratory and establish a utilization-oriented data base for alternative fuels in both contemporary and advanced heat engines.

The Department's fiscal year 1985 budget request for vehicle propulsion R&D provides \$15 million for proof-of-concept engine development and activity in ceramic component development under the automotive gas turbine project. A total of \$2 million has been requested for continuation of the heavy duty transport technology project which will focus on establishing a technology data base for industry development of the adiabatic diesel engine. Component development will continue on ceramic components and coatings, solid lubricants, and gas bearings, as well as efforts in system integration with implementation of single-cylinder test and evaluation capability.

We believe it is essential that the results of our R&D programs be disseminated in a manner that is most sensitive to the needs of the industry and the public. Therefore, we are requesting \$1.5 million for technology transfer, assessment and transfer activities in vehicle propulsion R&D. For electric and hybrid vehicle R&D, \$6.8 million has been requested, and these funds will be used to continue the development of experimental aqueous battery systems, flow battery systems, and a number of integrated propulsion systems, including advanced power trains.

The fiscal year 1985 budget request provides \$17.6 million for the advanced materials development program. Of these funds, \$7 million will be used for research in the fundamental areas of ceramic materials processing, design methodology, material characteristics and performance under stress, and useful life prediction. The re-

maining \$10.6 million will be used to complete construction of the high temperature materials lab.

We have requested \$1.5 million for the alternative fuels utilization program for fiscal year 1985. These funds will be used to conduct a systematic investigation into the fundamental behavior of alternative fuels in both spark ignition and diesel engines, focusing on alcohol and synthetic fuels. We will also develop and maintain data bases on physical, chemical, and combustion properties of alcohol and other fuels derived from oil shale, coal, and biomass. Additionally we are requesting \$1.9 million for program direction and \$3 million for laboratory equipment needed to support the research activities of the advanced materials and electric vehicles programs.

Finally, let me conclude by emphasizing that we realize we are going to be much more oriented toward increased energy efficiency, and view it as a significantly important energy resource, a resource that must be managed like any other. Our focus is on increased productivity and leveraging our energy dollars to get the greatest possible return on our expenditures for energy.

We see energy conservation R&D in the field of transportation as a very important part of our research portfolio, and we believe that development of new, efficient energy technologies will result in a constant, long-term reduction in energy consumption, and will have a positive economic effect in both the transportation sector and in the Nation as a whole.

We are pleased to have the input that we have gotten from the Congress, and feel we are coming closer to the interests of Members of Congress in general and in particular this subcommittee. Thank you very much, Mr. Chairman.

Mr. GLICKMAN. I want to just run quickly through, so I know exactly where your request differs both from what you requested last year as well as perhaps what was appropriated last year.

Now as I understand it, you are requesting the termination of one of the gas turbine contracts or a merger of them and, therefore, we would end up with one now instead of two.

Mr. COLLINS. That's basically right, Mr. Chairman. What we have suggested is that one continue along the path it's presently on and one be focused on the ceramics.

Mr. GLICKMAN. So what would you do? Would DOE, then, just choose one of the two?

Mr. COLLINS. No; there would be an evaluation panel that we put forth in the original contract, I believe, and that they were aware of, that will make that evaluation of which one of the two should proceed along the gas turbine route and which one should do the work in the ceramics area.

Mr. GLICKMAN. And then what happens to the other one, again? I was not clear about that.

Mr. COLLINS. One will be in the gas turbine engine, and proceed along those lines, and one will do work in the ceramics that are necessary as—

Mr. GLICKMAN. But that would be separate and independent from the actual development of a proof-of-concept of an engine itself?

Mr. COLLINS. Hopefully it will be coordinated, of course. Yes; the two would proceed down different tracks.

Mr. GLICKMAN. I am just wondering why you would want to spend \$5 million to continue ceramic component development by the losing contractor. What's the rationale for that?

Mr. COLLINS. Well, I think there's a degree of expertise there that they will have gotten through their efforts in this program. Ceramics across the board, of course, has received a great deal of attention in this budget. We probably will not be able to make progress in this and several other areas until we make some more progress in the ceramics area.

Mr. GLICKMAN. What are the chances that the two gas turbine contractors would agree to increase their respective cost shares, so that both could continue through the proof-of-concept idea with the funds you have requested, and would this be desirable?

Mr. COLLINS. Well, I think that would be a very interesting idea that we would like to look into, if they would be interested in that, Mr. Chairman.

Mr. GLICKMAN. Do you know if they have shown any interest in this as of yet?

Mr. COLLINS. I don't know. I want to defer to Mr. Streb on that.

Mr. GLICKMAN. Sure. Go ahead. Mr. Streb?

Mr. STREB. Yes; at this point I don't think that we can really make a precise determination with respect to the outcome of the negotiations with our two contractors. Recognize that the process that we plan to go through will, in effect, request each of the contractors to propose to put their best foot forward with respect to a program, a success-oriented program to complete the activity, with cost sharing being an important part of the overall evaluation.

Our evaluation, then, of the two proposed closeout activities will consider the technical merits of the approach that has been proposed, the resources and capabilities of the team, as well as cost sharing. I think, faced with the reality that we have limited funds available, there is a certain incentive for each of the contractors to maximize the cost share. I do think that one possible outcome would be that we would find ourselves in a position where both contracts could be supported.

Mr. GLICKMAN. OK. Now if you just stick with one, as you have currently proposed, as opposed to—I mean, as opposed to the current two competing contractors— what will not be done in the program?

Mr. COLLINS. Well, basically, Mr. Chairman, nothing. There is nothing that we won't be able to pursue on both levels. One is doing one shaft and one is operating on two shafts, and the one that wins in essence is determined by this evaluation group. We would be proceeding along either one or the other, along that gas turbine area.

Do you have anything to add to that?

Mr. STREB. Well, I think that in the proposed approach in which the same cost share would be maintained, and therefore we would have sufficient funds only to carry to completion one of the contracts, we would have a complete engine with all ceramic components produced by one of our contractors. The other contractor would produce only the technology associated with the ceramic

components. We think that's important because the approach that has been taken with respect to the specific choice of ceramics in addition to the fabrication technology is different in the case of each of the two contractors and, therefore, is of value in terms of the overall data base which is produced. So we do think that there is merit in an approach which would produce the technology associated with both ceramic systems, complete one engine, and offer the entire base of information to the industry.

Mr. GLICKMAN. But let me ask you this question: If you had your druthers and you had the money, would it be preferable to continue two contracts?

Mr. STREB. Well, I think that it certainly would be preferable to complete both contracts. We must take into account, however, the budget constraints, and that is basically what has been done in planning this, in this approach.

Mr. GLICKMAN. Mr. Carney, did you want to make a comment?

Mr. CARNEY. Along those lines, Mr. Chairman—and I appreciate your yielding—where one would be doing a continuation of work in the ceramics area, are we not doing that at the high temperature materials lab in Oak Ridge?

Mr. COLLINS. We are working on some generic opportunities in ceramics, Mr. Carney, that go across the board. This would be specifically related to what we are doing in the gas turbine, No. 1, and I'd like to say—possibly in furthering the answer to the previous question—that there are a great many projects that have merit but that don't fit within the budget constraints with which we're faced. Basically the difference between the two is to proceed on a single-shaft or a dual-shaft system.

Mr. CARNEY. If I may, Mr. Chairman—and I again appreciate your yielding—but we are also doing these types of high-temperature materials research through NASA and through the university community. Now my question is, if there is this redundancy and perhaps even a duplication of effort, would we not perhaps be more prudent to go back and, instead of giving them part of a research and development program, to allow them to continue the dual effort. Since they will be doing a substantial amount of work on the ceramics components and, I might add, getting a substantial amount of money, perhaps we could take that component work and let them continue and maybe find some duplicative efforts in NASA or in the university community or at the high temperature materials laboratory, and then continue the two programs. Maybe something could be worked out.

Mr. COLLINS. Well, I'm glad you mentioned that because a great many people are not aware that we have been pursuing some coordinating efforts. As you say, this is being done with NASA, the Department of Defense, and other departments in the Government. We have formed some formal coordinating groups to make sure there isn't that overlap, Mr. Carney, both within the departments of our Government and also in relationship to some of our foreign friends. We have about three different groups in the ceramics area alone that are pursuing this to be sure that we don't duplicate it.

Mr. CARNEY. What are we talking about for dollars if we were to continue the pursuit of the two engine concepts?

Mr. COLLINS. It would be about an additional \$5 million.

Mr. CARNEY. And that would be over and above the \$5 million that you're giving the—I hate to use the term “loser”—but the one who is not selected as the company to continue with the engine, so we're talking \$5 million, and maybe with some coordinated effort to save some money in ceramics research, we might even be able to shrink that down, and for a couple of million dollars perhaps we can keep both engines alive and well. I see benefit to that. You have two schools of thought: You have competition, and there is nothing better than competition to promote proficiency, particularly in this type of work, and I think the cost might be less than expensive considering the R&D effort in ceramics materials that is going on in all other areas.

That was what I was trying to pursue.

Mr. GLICKMAN. Well, I would just indicate I am sure the contractors would argue that it is not possible to develop ceramics without putting them in an engine to see if they work or not. While you could do some abstract ceramics work, I would almost rather not provide a consolation prize and let that work be done somewhere else, and so I think that this committee might want to seriously consider something along the lines that Mr. Carney talked about.

But let me just ask you specifically: What additional resources will be needed to finish the gas turbine project if we do it as you have proposed and if we would do it with two contractors? Do you know what we're talking about?

Mr. COLLINS. Yes; basically the base number here would be about \$15 million if we do it the way that we have proposed, and it would be about an additional \$5 million if we proceeded down both paths, Mr. Chairman. Of course this discounts what we may find in the cost-sharing in the negotiation process.

Mr. GLICKMAN. OK. Let me ask you a couple of questions and then I will proceed down and we will come back again.

That \$5 million is for the first year?

Mr. COLLINS. Yes, sir.

Mr. GLICKMAN. It's more than that after this. You're talking about 1 year?

Mr. COLLINS. Yes, sir, fiscal 1985.

Mr. GLICKMAN. What about down the line, down the road? What are we talking about?

Mr. COLLINS. See if we can get an estimate on that.

Mr. STREB. Well, let me try to take that.

We anticipate at this point that the approach that we had proposed would have completed one engine and would have completed ceramic development work on the other. At the end of that period of time, if all goes as planned, one would have an operating engine which met the specifications, with some testing and evaluation work having been completed.

I think at that point one needs to make the decision whether the Government needs to remain involved at all. If we were to be involved, I think it would be in the form of providing some assistance to the contractors or to industry to do further evaluation on that completed engine or, if you were to pursue two engines, in the case of both engines.

Mr. GLICKMAN. OK. I'm going to want to follow that up more later, but I want to move quickly to Stirling engine. Three years

ago when DOE proposed terminating the Stirling—DOE, and not you, Mr. Collins—the technology would never be used, but not that the industry is starting to show some interest you say now that you have proved the concept, and I want you to comment on that. Have you really proved the concept when Mod-1 doesn't meet the 30-percent fuel efficiency goal in the act, and shouldn't we go ahead with completing a Mod-2, and if we did that, how much would it cost?

Mr. COLLINS. Well, I think on the first question, Mr. Chairman, we think by the end of fiscal year 1984 we will have completed proof-of-concept, and it is the opinion of the professionals in our department that we will achieve that 30 percent. If we were to complete the MOD 2, it would take approximately 3 years and approximately \$42 million to complete.

Mr. GLICKMAN. Quickly moving to two other areas, one having to do with the alcohols, apparently you are proposing \$1.5 million for alternative fuels utilization. From what I read, it focuses on the technical problems associated with use of synthetic fuels and methane, and the data base for alcohol fuels will be completed in 1984. I wonder if you could just tell us essentially what you are going to be doing in the alcohols and what you feel you ought to be doing in the out years?

Mr. COLLINS. In the alcohols we hope to have a comprehensive data base when we are done, so that we have a handle on the efficiencies, qualities, and the properties that are involved that would be perceived as acceptable in the scientific community. We hope to do the same thing, basically, in the hydrocarbon and alternate fuels areas the following year, that was our—

Mr. GLICKMAN. Are you saying that would be—what are you talking about in terms of hydrocarbons, though? Synthetics?

Mr. COLLINS. Synthetic fuels, yes.

Mr. GLICKMAN. And what about a methane, natural gas as a motor fuel? The same thing?

Mr. COLLINS. Separately we have \$200,000 in the budget for fiscal 1985 on methane. I would like Mr. Streb to detail some of the activities we are going to do there.

Mr. STREB. We envision a rather modest effort in methane—\$200,000—which will be focused on containment, alternative containment, storage technologies, as well as the emissions, emission characteristics, and problems that are peculiar to methane.

Mr. GLICKMAN. Finally, let me—go ahead. Did you have something else to say?

Mr. STREB. [Shakes head negatively.]

Mr. GLICKMAN. I'm going to come back on that, too. Finally, I want to ask quickly about battery, electric vehicle research. Virtually everyone familiar with the problems of electric vehicles says we need big advances in battery technology, yet you are reducing your battery R&D, and that includes ending work on lead-acid and nickel/iron. Why? Isn't this the kind of long-lead, high-risk research that you say the Government should be doing?

Mr. COLLINS. Well, we're going into some batteries, Mr. Chairman, that possibly will be even more productive. We think that by the end of fiscal year 1984 we will have fairly well concluded our work in the near term aqueous battery area and we will be looking into batteries such as the sodium/sulfur batteries and others like

this where we are really at the startup of our work on these and it won't be as expensive as when we were at the zenith of our work on the basic batteries.

Mr. GLICKMAN. Well, you say you're moving ahead. What kind of batteries? What are these technologies? Aluminum oxide? I'm just trying to figure out what kind of batteries you're talking about.

Mr. COLLINS. Why don't you go ahead on that.

Mr. STREB. In the transportation program there is a considerable part of the budget request this year devoted to various propulsion technologies, as well as to advances in the battery systems. Sodium/sulfur is one of the advanced batteries that will be addressed in the current program. Also, there will be some advanced vehicle work, integration work on next generation technologies which would include aluminum-air and also fuel cells, looking at the problems which are peculiar to those particular storage systems within the vehicle.

I think we should also add that, though there is a somewhat reduced budget in vehicle systems and some part of that reduction relates to the batteries, there is a very substantial battery program as part of our electric energy storage. The precise number is in the budget, but I believe it is on the order of \$16 million that is related to electrochemical research at large. Much of that is very basic but quite a bit of it is also approaching the applied, approaching the point where it is applicable and within reach of the vehicle.

Mr. GLICKMAN. OK. Well, my numbers indicate that in Fiscal Year 1983 the appropriation for electric and hybrid vehicle R & D was \$13.8 million, down to \$11.7 million in fiscal 1984 and \$6.8 million in fiscal 1985—that's your request—which means about a 50 percent request based upon last year's appropriation. What I'm trying to figure out is what you are stopping, what you are going ahead with, because you're going to spend about—at least on your request you want to spend one-half of what you spent last year.

Mr. STREB. Yes. I think that there are several major reasons for this reduction. The first is in completing, really, the work that we had contemplated in lead-acid and nickel/iron, the relatively near-term aqueous batteries. We feel that we have gone about as far as we need to go in terms of supporting the development of that particular technology.

The hybrid vehicle was an expensive part or a substantial part of last year's budget—1984, that is—and we see that at a point where it is phasing down. We are continuing some effort this year but it is with carryover funds from the previous year.

A substantial part of last year's effort was in an alternating current—a.c.—propulsion vehicle drive and the associated batteries for a passenger car. The vehicle, the prototype vehicle that we had planned there was completed and has been delivered to our national labs for testing. No funds are going to be required in that area.

And the test and evaluation program, which is really a multifaceted effort, has been cut back a little bit; though that represents a small part of the total scaleback, about \$600,000, as I recall.

Mr. GLICKMAN. Do you, Mr. Collins, think that this program is consistent with the desire to, you know, to move ahead with this kind of technology? I mean, are you comfortable with the numbers in the electric program?

Mr. COLLINS. Mr. Chairman, I think because we have the vehicles that have been delivered by Eaton, and we have one a.c. and two d.c. that we are proceeding on—the fact that we are coming to the conclusion, we think we will in fiscal 1984, of most of our basic battery work—that this is a startup. This is a good startup and enough to take a look at the potential in several of the more advanced batteries that we have been working on. Then it may be possible that there are such opportunities there that we will want to come back and suggest a much bolder program in the future.

Mr. GLICKMAN. Thank you.

Mr. Carney?

Mr. CARNEY. Well, thank you again, Mr. Chairman.

Mr. Collins, do you believe the auto industry will ever accept the Stirling engine?

Mr. COLLINS. Well, I think that the enthusiasm hasn't been overwhelming, Mr. Carney, but I do—

Mr. CARNEY. So has mine. [Laughter.]

Mr. COLLINS [continuing]. I do think that we have in the last year seen interest, and I think in fact it's almost fair to say more than we have in all the previous years put together. Like so many of these areas that we're at in the basic and applied research area, it's very difficult to tell when and/or if that will be pursued vigorously by the private sector.

Mr. CARNEY. When you say interest, is that General Motors' willingness to test the Stirling engine? Is that what you're talking about?

Mr. COLLINS. Yes. There are five or six examples like that, sir.

Mr. CARNEY. Let me ask you about the most important example, in my opinion, for willingness. Has General Motors put any money into research on this?

Mr. COLLINS. My impression is that they have not yet, sir.

Mr. CARNEY. Have any of the big three automakers put any money recently on the Stirling engine?

Mr. COLLINS. Not that I know of, Mr. Carney.

Mr. CARNEY. I always say, you put your money where your mouth is.

How practical do you think the electric car is today?

Mr. COLLINS. Well, we're continuing to make progress on that. There are certainly problems, and there's a great deal of problem, obviously, with the public perception by those who don't drive many miles and probably could utilize electric vehicles but do not. I think that that is very nascent now but I do think that a lot more people could utilize it than presently do.

Mr. CARNEY. What types of performance are we looking for as far as range?

Mr. COLLINS. Presently?

Mr. CARNEY. Yes, in the electric motor.

Mr. COLLINS. In the 60 to 70 mile area, I believe, is—

Mr. CARNEY. For recharge or swapping and that type of thing?

Mr. COLLINS. Yes, sir.

Mr. CARNEY. What type of initial cost will we be looking for? Let's take someone like the post office, for instance, who probably could utilize these types of vehicles in their day-to-day work. Do

you have any idea what type of cost we would be talking about, the vehicle and the infrastructure necessary to support the vehicles?

Mr. COLLINS. The infrastructure I do not, and maybe possibly one of our experts has. I think in the vehicle per se, if we're just talking about electric and not the hybrid, we're in the ball park with our present—Paul, can you talk about it?

Mr. BROWN. Yes. Paul Brown, the head of the electric vehicle program

The post office vehicle that you're discussing, stopping, starting, is on the order of 20 percent higher in initial cost. However, the maintenance and operating cost is less, is less than a gasoline engine. The post office has 350 such vehicles at Cupertino, and the post office separately now has 32 new kubvans that they are experimenting with, so the actual initial cost—because of the economies of scale, where they're being made in fifties rather than hundreds of thousands of trucks, is about 20 percent higher. However, again, the maintenance costs and operating cost are much less.

Mr. CARNEY. When you're looking at the economies of scale and you're building 350 hybrid-type vehicles and it's only 20 percent higher, I would think that there would be a great deal of potential for this type of vehicle in that type of application, post office—I hate to mention any of their competitors but, you know, the people that are taking the cream from the post office and delivering parcels throughout our communities. They have an enormous potential for this type of application.

Mr. BROWN. The post office R&D group right here in Rockville agrees with you, but now we're talking about an all battery-powered, an electric. The hybrid is a little different operation. With the hybrid, you have the potential of no limitation of performance, no limitation of range and/or refueling. The hybrid vehicle is being looked at as new technologies are becoming available.

If you couple, now, into the hybrid, rather than a lead-acid battery, a nickle/zinc battery, for example, you have improved its performance significantly. In addition, if you have in the hybrid a very small internal combustion engine that goes on and off at the stop sign. All of the automobile industries, including Toyota and Volkswagen, are developing such engines where at the stop sign the motor goes off, and when you hit the accelerator pedal it comes on again. You don't lose energy during idling.

Mr. CARNEY. Right.

Mr. BROWN. That kind of engine coupled with some of the new battery technology is being looked at as a potential of a hybrid application for the future. Ford Motor Co. is looking at that through their studies of the hybrid concept.

Mr. CARNEY. It sounds very exciting. [Laughter.] I meant that. I would just simply like to thank you all for coming with your testimony today. I am sure, Mr. Collins, this will be the first time that you will be working with this subcommittee, and I can assure you that we work in a very bipartisan fashion. We will probably be sitting down, calling up and trying to reach some types of accommodations. I am sure you will find it enjoyable, and we are looking forward to working with you.

Mr. COLLINS. Thank you very much, Mr. Carney.

Mr. CARNEY. Mr. Chairman, I unfortunately have to run. OK? Thank you.

Mr. GLICKMAN. Mr. Boehlert?

Mr. BOEHLERT. Thank you, Mr. Chairman.

Mr. COLLINS, am I correct that the Stirling engine project, the R&D is intended to show that the Stirling engine is 30 percent more fuel efficient than conventional engines?

Mr. COLLINS. Yes, sir.

Mr. BOEHLERT. Am I reading your statement correctly, that with all the 4,000 hours of performance testing, you are looking for—by the end of the year you are saying a maximum efficiency of 37 percent, and you have already exceeded that? You have already declared it a winning—

Mr. COLLINS. That is the view of our professional staff.

Mr. BOEHLERT. But you're not there yet.

Mr. COLLINS. No, sir. We're over 30 right now.

Mr. BOEHLERT. You're over 30 right now.

Ms. FITZPATRICK. I think there is a confusion here between overall efficiency and improvement in efficiency of our engines. Paul had better answer.

Mr. BROWN. Actually, the testing that you are seeing there is with the MOD 1 upgraded. Indeed you are seeing that kind of percentage of improvement in fuel efficiency that you can actually achieve in the upgraded now to a research engine that we are talking about, also characterized as a MOD 2 design. The design will be completed, and some of the components made, in our proposed Stirling engine for fiscal year 1984. That work will continue, but in 1985 we do not propose that we complete the complete MOD 2 engine, which would be another 3-year development.

Mr. BOEHLERT. Three years and \$42 million, is that—

Mr. COLLINS. Yes, sir.

Mr. BOEHLERT. I don't want you to be clobbered by Mr. Carney's objective analysis of the Stirling engine. The view isn't necessarily shared by all of us who are privileged to sit up here.

Mr. COLLINS, you were interrupted by Mr. Carney before you had a chance to elaborate a little bit. He gave you the GM example, and I think you indicated—a least from my notes—that there are five or six others?

Mr. COLLINS. That is correct, Mr. Chairman, and I would be glad to provide that for the record. There are five or six that have expressed interest and pursued it much more vigorously in the past. Like I said, I think it's more than the accumulated interest of all the past years combined, and that is a very positive sign, I think, of their interest.

[The information follows:]

INDUSTRY INTEREST IN STIRLING ENGINE

Members of the automotive industry who have shown an interest in the Department's Stirling engine program are: (1) General Motors Corporation, (2) John Deere, (3) Cummins, (4) Ford Motor Company, and (5) Deimler-Benz.

Mr. BOEHLERT. Well, isn't there a risk of ending it a little bit too early?

Mr. COLLINS. Well, that's a very tough call on all of this basic and applied research, Mr. Boehlert. I think that we're talking

about the progress that we hope to make in this upcoming fiscal year and the interest that we hope will be expressed by the private sector in adopting that. Assuming that the proof-of-concept has been completed, neither rejecting it nor adapting it. So yes, sir, that's a tough call in all of this basic and applied research that we're doing.

Mr. BOEHLERT. Well, I'm glad to hear it was a tough call because I think Mr. Carney sometimes tends to paint things in black or white, and this is one of those he painted in black.

Thank you. No further questions.

Mr. GLICKMAN. Thank you, Mr. Boehlert.

Mr. McCandless?

Mr. MCCANDLESS. When we talked about vehicles stopping at lights and not operating and so forth—a little explanation—I come from a part of the country where golf carts have been around for quite some time. Harley-Davidson, Yamaha, and many others have been manufacturing golf carts that stop and start whenever you want them to. You don't have to run them or idle them. Electric golf carts, everybody's trying to find a way to improve the distance that the cart will travel, and about the only way that we have ever been able to do that is to reduce the overall weight of the cart itself because the battery propulsion doesn't seem to have any real progress.

Getting back to why we are here today, the thing that keeps coming back—and it's kind of an instant replay of last year's hearing, this Stirling engine—is the fact that the Stirling engine as a stationary engine, in such a mode as pumping water in a field, agricultural—we keep wandering in and out with this thing, I don't know why—is an excellent engine because you have no need for a power to weight ratio; and that when we talked about the completion of the MOD 1 and we were going to prepare for the MOD 2, one of the chief objectives was to reduce the overall weight of the engine yet give you the same performance. Are we headed in that direction with this? Is there anything significant taking place since last year in this thing, when we approved the funding of that?

Mr. COLLINS. Mr. McCandless, we certainly think that there are very promising possibilities in the stationary utilization of the Stirling engine, but as far as in reducing the weight ratio, I would like to defer to Mr. Brown on that.

Mr. BROWN. That weight consideration is one factor but not a principal factor in the MOD 2 development. Actually, reliability in going through the transient states has been, throughout the development of the Stirling engine, the problem—the sealing problem of the hydrogen, for example—and significant progress has been made and continues to be made by MTI, but we are of the view that that work, the technology of developing that, will have been sufficiently complete this year that the auto industry can make their decisions as to whether that Stirling engine can be placed in their vehicles.

We have mentioned the testing program, where this committee did authorize and it was appropriated that we provided engines to John Deere Co. and General Motors for their testing and evaluation. Ford and others are looking at those tests, both on the dynamometer and in the vehicle.

So, yes, there has been technology improvements, in that engine, but whether or not it would be applied in the automobile is a decision that the auto industry we believe can make based upon their own testing of those engines as well as the new developments that are coming into the MOD 2 design.

Mr. McCANDLESS. When we look at the future and what we might have in the way of a powerplant, in a scale of 1 to 10 with all of the other technology, where would you place the Stirling engine potential?

Mr. BROWN. I'm not sure which the 10 are.

Mr. McCANDLESS. Well, everybody knows what a 10 is. I don't see them very often, but—

[Laughter.]

Mr. BROWN. Certainly if we are looking at the development of engines for the automobile, with the developments by the auto industry itself in the improved economy of spark ignition, stratified charge, then moving to the diesels, the Stirling is probably lower in the estimation of how it can be used in the mobile application. Again, the Stirling engine can be used for other applications other than in the automobile. It ranks pretty low in the—I guess the only one lower is probably the Britalis that we've been hearing about quite a bit.

Mr. McCANDLESS. Well, what we're trying to do here is, we're trying to develop engine components for automobiles, which is the major user of fuel oils, and so when we talk about a stationary engine for some purpose that takes on a rather secondary importance because of the percentage of fuel burned by stationary engines. That's my concern, is that we don't try to put too many eggs in the basket at one time but concentrate on those things that are the most promising in terms of powerplants and try to get something on line that has a significant fuel saving, rather than to keep shooting with a shotgun and hope that someday we come up with something out of all of these pellets that were shot into the air, so to speak.

The other part of it is that the turbine program that you're recommending a cutback in, is there anything there between the dual shaft and the single shaft that the technology would not provide, once you had whatever you're looking for in the way of an end result, if you discontinued one or the other? Aren't you talking about the same principles and the application of those principles to a finished product?

Mr. STREB. Yes, I think that that's true. The principles are the same.

Mr. McCANDLESS. So you wouldn't necessarily need to have two research programs going on at the same time, one labeled "twin shaft," one labeled "single shaft."

Mr. STREB. We don't believe so. That was the reason for our proposal.

Mr. McCANDLESS. Right. The chairman was talking about this, and I had pangs of maybe he was going to want to up the budget, and I wanted to let my thoughts be known to our illustrious chairman about upping budgets, since we've been talking about that very strenuously.

Mr. GLICKMAN. If the gentleman would yield for just one moment—

Mr. McCANDLESS. Yes, certainly.

Mr. GLICKMAN. I want to make sure. You say you don't—as I understood it, you said if the money were available or if other arrangements could be worked out, it would be your preference to go ahead and complete both proof-of-concept ceramic technologies, single and double-shaft. Right?

Mr. STREB. That's correct, Mr. Chairman. I did say that. I think that that gives industry the maximum options. However, I think the concept is proven with either approach, which was the answer I provided to the earlier question.

Mr. GLICKMAN. OK. Thank you.

Mr. COLLINS. Mr. Chairman?

Mr. GLICKMAN. Yes.

Mr. COLLINS. If I can add just briefly on that, there is something else to be gained. We think it is so marginal, that we came in with the proposal for one, pursuing one, Mr. McCandleless.

Mr. McCANDLESS. What would be your guess, based upon the current level of knowledge, that you would have available, in production, for purposes of utilization as a powerplant, a ceramic component part engine? How many years is it away?

Mr. COLLINS. In the neighborhood of three, Mr. McCandleless.

Mr. McCANDLESS. Would this be sophisticated enough for mass production?

Mr. COLLINS. I believe that certainly there was an indication that the Japanese felt so in our automotive show in Detroit this last year. I don't know many people who disagree with that, although that is not entirely ceramic.

Mr. McCANDLESS. And what are we talking about if we take a current design engine of a certain displacement and compare it to a comparable ceramic, as far as comparable weights are concerned?

Mr. BROWN. Depending on the horsepower range, with all of the drive system—

Mr. McCANDLESS. Well, take any horsepower range you want. We're talking about 3 liter and smaller engines now as being the major emphasis as far as automotive powerplants are concerned.

Mr. BROWN. Well, as far as weight is concerned we can—ceramics, by the way, can make them lighter because of the way it is applied. No one has put this all together as a complete vehicle system, but equal to or slightly higher in weight is what one can do with a ceramatized gas turbine engine.

Mr. McCANDLESS. Wait a minute. You said—you tacked on "gas turbine." I was talking about reciprocating.

Mr. STREB. Let me try to address that. I think you were talking about a reciprocating engine—

Mr. McCANDLESS. Yes.

Mr. STREB [continuing]. And this would be the adiabatic diesel, for example. I believe that for comparable displacement you have two things in your favor with a ceramic engine. One is the ability to operate at much higher temperatures and therefore higher efficiencies, which will give you a higher performance and also a higher specific power output, but in addition to that the materials generally are lighter, and under certain circumstances— and this

is the reason for a very mammoth, large effort in ceramics—can be stronger. So intuitively I think that we are looking at the potential for some considerable advantage.

Mr. McCANDLESS. We are 3 years away from something that one could say would be a pilot model?

Mr. STREB. Yes, yes. I think we are possibly 3 years away from something that might be a pilot model. A reciprocating engine production could be further away than that. Paul, do you—

Mr. BROWN. Yes. Actually when we're talking about, again, the piston engine—and I misunderstood your question—as we are working with the adiabatic diesel that you see in the proposal, we're talking about the 3-year time would see the proof-of-concept. You are probably within maybe 6 to 7 years before you are actually into production of those.

Mr. McCANDLESS. Right.

Mr. BROWN. I'm talking about cylinders and the sidewalls and the whole vehicle itself, not just the engine.

Mr. McCANDLESS. Mr. Chairman, I have one other question, with your permission.

Mr. GLICKMAN. Go ahead. Sure.

Mr. McCANDLESS. There is an intangible here that doesn't deal directly with the R.&D. that we're talking about, but the attractiveness of any kind of an engine component is in direct proportion to its cost of operation, including the fuel costs. The oil industry has, over a period of time, dealt a severe blow to the attractiveness of the diesel engine as it is to be applied, particularly in the passenger car and light duty, because of their increasing the cost of diesel fuel to a point now where in most cases it is the cost of 87, 89 octane equivalent low-lead, which does not provide you anything in the way of a fuel savings, so you're going to have to pick it up on the other end in terms of life expectancy of the engine and the maintenance and operation. Then you are going to have to sacrifice the performance, and then you crank in the fact that that engine option is going to cost you considerably more, so the diesel no longer is attractive because all of a sudden the oil industry decides they're going to hit the high road with these things when they can get far more gallonage out of a barrel of oil, distilled diesel fuel, than they can any of the other components.

What are the Department of Energy's thoughts on those things? Do you want to continue to see the diesel engine expand, or are we saying that it has reached its peak and we're going to kind of phase it out, using cost of fuel as one of the reasons?

Mr. COLLINS. We're doing a great deal of work on that, because we do think that there is a significant role for diesel in the future. We're going to be able to run, possibly at the higher temperatures that would be necessary to make it more efficient if our work in ceramics is successful. I would like Mr. Brown to expand on that.

Mr. BROWN. Our concentration is really on the heavy-duty transport area, where we see in the future where certainly the heavy-duty truck and trailer operators look at their maintenance cost and operating cost, so the first efforts here are certainly in the heavy-duty transport area. If you do it in that area and have proven it, it is possible that it can come back into the passenger car area. We do see projections of the future in which the highway traffic with

the heavy trucks are going to be using more and more of that petroleum because they are less and less efficient than the passenger cars, as they are becoming more efficient, so our concentration is for the heavy-duty transport kind of engines first.

Mr. McCANDLESS. We're talking here about the free enterprise system and how to merchandise fuels. Does the Department of Energy ever look into something like this, encouraging industry to take a look at its pricing schedules, without regulations and over-seeing and that kind of thing?

Mr. COLLINS. I would like to supply the answer for that for the record, if we could, Mr. McCandless.

[The material referred to follows:]

One of the principal strategies for achieving the National energy policy goal of fostering an adequate supply of energy at reasonable costs is to "minimize federal control and involvement in energy markets . . ." The ability of the market to respond to changing economic conditions has been enhanced significantly by a national energy policy that limits the federal role to the functions of establishing the boundaries of national security and public health and safety within which the market operates and of complementing private initiatives through basic and applied research and development and economic management of publicly owned resources. Thus, the Department does not attempt to influence industry pricing practices, preferring rather to permit individuals and businesses to apply and react to their respective views of the future and to reap the benefits, as well as bear the risks, of their decisions.

Mr. McCANDLESS. All right. My concern here is that diesel-operated passenger cars are more efficient as far as mileage per gallon of fuel consumed, and other than the emission levels of those particular units they have that tremendous advantage of being able to supply far greater distance for less in the way of fuel, which is what we're all looking for here in the economy of operation and the conservation of our resources.

Mr. COLLINS. Yes, sir, I think that our work in the heavy-duty area this year and probably in subsequent years looks like it may have some very excellent possibilities in efficiency. We may be able to extrapolate from that for the passenger car as well.

Mr. McCANDLESS. Thank you, Mr. Collins, Mr. Streb, and the others.

Mr. COLLINS. Thank you, sir.

Mr. McCANDLESS. Thank you, Mr. Chairman.

Mr. GLICKMAN. Sure. Thank you, Mr. McCandless.

I would like to move to just briefly talk about the materials issues which you referred to quickly in your remarks. A number of industrial representatives have recently met and called for establishing a national research and development program to develop structural ceramics technology. In your view, is the advanced materials development program sufficient in fulfilling a national research program in advanced ceramics? And that is not just transportation or energy.

Mr. COLLINS. Yes, Mr. Chairman. I appreciate the opportunity particularly to comment on that because it is one of the areas of greatest increase in our budget, as you could well see. It included trips to view our facilities and, as a matter of fact, some concurrent suggestions along the line of equipment that we will need to be state-of-the-art on this.

We think, and we plan for our program to accomplish the goal that would be suggested by what you— by your comments, because it's absolutely vital to a wide range of activities, not only in the transportation area but within the Government. That's why we have the three coordinating groups that are working, both interdepartmentally and also with our allies abroad.

Mr. GLICKMAN. Okay, but you think, though, that the program is sufficient to fulfill a national program in advanced ceramics? That's what I'm trying to—

Mr. COLLINS. We think so, and that is what we plan on. We're proceeding down the road on that, Mr. Chairman, and certainly will review it.

Mr. GLICKMAN. What are the total projected costs of this program?

Mr. STREB. Mr. Chairman, at this point I think that we are looking at a program which is really not basic research. It's applied research. We propose \$7 million for this year, and I would see a level of effort that would stay in that same general region.

I might point out that the program is in its formative stages. We're talking about an activity which has grown in the last couple of years. It's going to be occupying a new laboratory, but we also are looking for means by which we can better communicate with the outside—that is, outside of the Government—both with industry and with academia, and to make them an effective part of the team which will develop these technologies that we think are so important.

To do that, one new initiative contained in this year's budget is a fellowship concept, in which we intend to seek nominees—that is, distinguished scientists from the outside—who will work in our materials program at Oak Ridge. We will also be looking for distinguished scientists within our universities who will become an integral part of the effort.

Mr. GLICKMAN. How much are you talking about allocating for the fellowship program?

Mr. STREB. The fellowship program is a total of 17, and it is divided between—we have a fellowship program also in the electric vehicle program—but I believe that the bulk of it is in the materials program. My recollection is it's \$800,000 of the \$7 million is allocated to the fellowship program.

Mr. GLICKMAN. Now what I would like to ask you is, how does your work in materials differ from work that is being done in other parts of the Government?

Mr. STREB. Naturally, the work that we are doing in materials has as its ultimate objective satisfying some goal within conservation. We have in transportation programs, a substantial ceramics program that is oriented toward transportation needs; other parts of conservation in like manner. I think that we have to point to, within the Department of Energy itself, we have a coordinating body that is chartered within Energy Research under Dr. Trivelpiece, Director of the Office of Energy Research, whose purpose is to coordinate all materials work, and the specific orientation tends to be toward high-temperature materials within the Department of Energy.

That body, in turn, works with a larger coordinating body that coordinates among Government agencies, and as Mr. Collins has mentioned, there is another body that we work with which actually looks internationally at needs, so between these various efforts we feel that our program will be an integral part of the whole and a well-coordinated part of the whole. There certainly are materials needs, that is, ceramic materials needs that go beyond the specific needs of transportation and conservation, but our focus has to be on that.

Mr. GLICKMAN. All right. Well, you are obviously coordinating your ceramics research with efforts like what NASA is doing. Is that correct?

Mr. STREB. That's correct.

Mr. GLICKMAN. How is coordination being carried out with the Department of Defense and the National Science Foundation and the National Bureau of Standards? I guess one of the fears I have is that we have just a tremendous amount of materials research being done in a variety of governmental agencies. I don't know how much is duplicating each other, and I want to know if the right hand is knowing what the left hand is doing.

Mr. COLLINS. Mr. Chairman, the group that Mr. Streb mentioned is, through our Energy Research Division at the Department of Energy, coordinating with all of the agencies that you mentioned plus some others, and their whole focus is to preclude that duplication, but that's something that we have to constantly review.

Mr. GLICKMAN. Well, who is setting the priorities and goals for all of these different materials programs?

Mr. STREB. The chairman within the Department of Energy-wide coordinating body is an employee within Conservation and Renewables.

Mr. GLICKMAN. So he is setting yours, in the Department of Energy, right? Or he is the chair of the group that sets those priorities?

Mr. STREB. Yes, sir. He is the chair for that body setting the priorities. There is a larger coordinating body that coordinates among the agencies, but I really think that we should get this information and furnish it to you for the record.

Mr. GLICKMAN. OK. I'll tell you what my concern is. My concern is, I want to know how these programs differ from each other. I realize you can't speak for them all but, you know, are there different materials being required and considered? How different are the requirements and how are those requirements determined? I mean, I think it's great that we're building a new lab at Oak Ridge. I just want to make sure that the same work isn't being done here. You talk about having a transportation focus, but other work may also have a transportation focus.

I am also concerned about the fact that Japan and Europe have very large investment going on right now in ceramics work, and I still don't think that our total aggregate commitment in this country equals theirs. I wonder if you have any information about their investment, their emphasis on materials work, what it has been doing lately?

Mr. COLLINS. Well, Mr. Chairman, they have a relatively active pursuit of this. They are working with MITI. They were over here—

Mr. GLICKMAN. You're talking about the Japanese, now?

Mr. COLLINS. Yes, sir. They were here 2 months ago. We conferred with them. We are talking with them on a relatively frequent basis, but I think that probably for this committee we should get the best possible documentation that is available on numbers, if there is such, as far as budgets that are committed to this for the respective governments so we could be accurate for the record.

Mr. GLICKMAN. Yes. I think it is an appropriate function for this Congress to find out what other nations are doing, and the best you can, if you could do that for us we would appreciate it.

Mr. COLLINS. I'll be glad to, Mr. Chairman.

Mr. GLICKMAN. Mr. McCandless?

Mr. MCCANDLESS. The chairman has touched upon a very sensitive area, and that is coordination of agencies doing basically the same research. Do I take it that you are satisfied that this research is being coordinated in a way to get the maximum bang for the buck for the basic research of a particular commodity or project?

Mr. COLLINS. Mr. McCandless, we are satisfied that the structure is in place for that. I personally am going to recheck that to be sure, so that I can get back to you and verify that no duplication is taking place. The Secretary and I are certainly as interested in that as this committee and, I am sure, the entire administration.

Mr. MCCANDLESS. Let me just take a minute of time to—let's take the ceramic research. How is that coordinated? Is it the Department of Energy's? Are you the chair for coordinating that or is there another department of Government that is the chair and you contribute? How does that functionally take place, the coordination?

Mr. COLLINS. Mr. McCandless, within the Department we have a coordinating body which is headed by someone in our conservation and renewables area; then, second, within the administration we have an interdepartmental team on which we are represented by our Office of Energy Research, our basic research that is being done in the Department. I think that the formal coordinating mechanism beyond that I would like to provide for this committee, along with an analysis of the final say on that, who has the final say.

Mr. MCCANDLESS. As we have said earlier, the Defense Department is doing something; DOC is doing something, maybe.

Mr. COLLINS. Yes, sir.

Mr. MCCANDLESS. The idea is that this is all you are sharing. Maybe you are assigning out certain aspects of the research. That is a concern that I think is basic to some of these committee discussions is, as the chairman pointed out earlier, that we don't wake up and find ourselves with three layers of duplication, all utilizing taxpayers' money to come to the same conclusion.

Mr. COLLINS. Yes, sir.

Mr. MCCANDLESS. That's the nightmare that someone who is elected, trying to do a job, wakes up in the middle of the night wondering how many offices and departments are doing the same thing.

Mr. COLLINS. That is the goal of the mechanism, Mr. McCandless. I want to doublecheck for you and be sure that is being accomplished as satisfactorily as this subcommittee and the administration want it.

[The material referred to follows:]

COORDINATION OF CERAMIC MATERIALS RESEARCH

To accomplish their respective missions, the Department of Energy, the Department of Defense, and other Federal agencies are conducting separate advanced ceramic research programs. The mission of the Office of Vehicle and Engine R&D (VERD) in the Department of Energy includes developing the ceramic technology for industry's use in advanced heat engines for transportation vehicles. NASA is developing ceramic technology for space applications and the Department of Defense for military applications. To coordinate the ceramic research and development activities and avoid duplication of effort, VERD uses the following six committees:

1. Bimonthly DOE-NASA Ceramic Coordination Committee

This committee was established by VERD to focus on DOE and NASA activities but includes other agency participation.

2. The Interagency Working Group on Ceramics for Heat Engines

This committee is chaired by a VERD staff member and includes participants from DOE, NASA, NBS, NSF, Bureau of Mines, and DOD.

3. The Defense Advanced Research Project Agency (DARPA) Interagency Steering Committee for High Temperature Materials

This committee is comprised of representatives of DARPA, Navy, Army, Air Force, NASA and DOE (VERD staff member).

4. The International Energy Agency U.S. Consulting Committee for High Temperature Materials for Automotive Engines

This committee is chaired by a VERD staff member and is made up of DOE, NASA, and ceramic and heat engine researchers from private industry.

5. The DOE Energy Materials Coordinating Committee (EMaCC)

This committee is made up of representatives from all Department of Energy organizational elements involved in materials research (Fossil Energy, Energy Research, Nuclear Energy, Conservation and Defense Programs).

6. The Industry-University Advisory Committee on Ceramic Technology for Advanced Heat Engines

Membership is currently being formulated and is being designed to include a representative cross-cut of industry and university personnel directly related to the program activities. The Committee will provide guidance and oversight to VERD's Advanced Materials Program.

A comprehensive five year program plan to develop ceramic technology for advanced heat engines was prepared for VERD by the Oak Ridge National Laboratory (ORNL) after extensive consultation with ceramic and heat engine industries, government research laboratories and the university research community. The Advanced Materials Program of VERD is based on the five year program plan prepared by ORNL which identified the research needs not being undertaken by industry, government or the university community. The publication and dissemination of the Program Plan for Ceramic Technology for Advanced Heat Engines to the research community is providing an additional mechanism for coordination of the research activities of VERD.

In the area of structural ceramics R&D, the estimated funding for FY 1984 and FY 1985 by the different government agencies is given in the Table below:

<u>Government Agency/Program</u>	<u>Funding (\$ Million)</u>	
	<u>FY 1984</u>	<u>FY 1985</u>
DOE		
- Conservation		
Transportation	12.3	14.3
ECUT	.6	1.0
Industry	2.3	2.6
- Fossil Energy	1.0	1.0
- Basic Energy Sciences	1.5	2.0
DoD		
- Army (AMMRC)	1.0	1.0
- Army (TACOM)	5.0	1.5
- Air Force (Carbon/Carbon-Chemistry)	5.0	7.5
- Other (Polymer Processing)	8.4	13.7
NASA	1.5	2.5
NSF (University Support)	<u>3.0</u>	<u>3.0</u>
TOTAL	41.6	50.1

Mr. McCANDLESS. Thank you.

Thank you, Mr. Chairman.

Mr. GLICKMAN. I would just like to follow on that for a minute. I think a concern I have in the materials is that, while there may be some discussion among agencies, that there is no coordination, there is nobody setting priorities. That's why we have a White House council, theoretically, and why this committee has been involved legislatively, and a very important issue, and so I'm not sure that you are the agency for setting priorities but, on the other hand, you are the agency that has jurisdiction over a lot of the work that is being done.

Mr. COLLINS. Yes, sir.

Mr. GLICKMAN. And I hope that you can try to answer some of the questions that we have asked today.

Mr. COLLINS. Yes, sir.

Mr. GLICKMAN. OK. Thank you very much, Mr. Collins. I appreciate your being here.

Mr. COLLINS. Thank you, Mr. Chairman.

Mr. GLICKMAN. I hope we weren't too rough on you. Tomorrow at 10 a.m. we have a hearing in this room with some of the contractors that may have contrary points of view to what you have said today, so we will all be interested in hearing that.

Thank you very much. The hearing stands adjourned.

[Whereupon, at 3:20 p.m., the subcommittee recessed, to reconvene at 10 a.m. on Wednesday, February 22, 1984, in room 2325, Rayburn House Office Building.]

[The prepared statement of Mr. Collins follows:]

PREPARED STATEMENT OF WILLIAM PATRICK COLLINS, UNDER SECRETARY, U.S.
DEPARTMENT OF COMMERCE

Mr. Chairman and Members of the Subcommittee, I appreciate the opportunity to appear before you today and provide information on the FY 1985 budget request concerning the Department's energy conservation research and development programs in the transportation area. The budget was developed in concert with the Fourth National Energy Policy Plan (NEPP-IV), published in October 1983, and fully supports the goals and strategies set forth in that document. I will summarize those parts of the Plan which are relevant to the subject of today's hearing, discuss highlights of the FY 1985 budget, and address the areas of interest identified in your letter of invitation.

NATIONAL ENERGY POLICIES AND STRATEGIES

The overall goal of our national energy policy is to foster an adequate supply of energy at reasonable costs. The policy recognizes that "adequate supply" requires flexibility in the energy system, with no undue reliance on any single source of supply. The goal of "reasonable costs" suggests economic efficiency within the energy system, so that energy consumers, individuals, commercial and industrial users alike, are not penalized by economic rigidities introduced into the system by ill-advised governmental regulation. The strategies for achieving this energy policy goal are:

- o to minimize Federal control and involvement in energy markets while maintaining public health and safety and environmental quality; and

o to promote a balanced and mixed energy resource system.

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The FY 1985 budget implements these strategies by supporting development of a mix of technologies that can contribute to both energy supply and improved end-use efficiency. In allocating our resources, we are concentrating on applying Federal funds only where they are most effective; in sponsoring longer-term, high-risk research and development where the potential payoff is high but which private industry cannot be expected to pursue. The budget continues the Administration's policy of not funding commercialization activities which are the proper province of the private sector.

TRANSPORTATION RELATED GOALS AND OBJECTIVES

The objectives of Department's energy conservation research and development programs in the transportation area are to contribute to improved energy efficiency and enhanced diversity of available end-use technologies. These programs provide the technology base necessary to support private sector efforts to develop more efficient technologies, and which serve as alternatives to those based exclusively on petroleum.

The importance of our efforts in this area is underscored by the fact that the transportation sector accounted for 27 percent of total U.S. energy consumption in 1983, and more importantly, 61 percent of U.S. petroleum consumption, up from 51 percent in

1973. During this period, the private sector has made substantial investments in more efficient transportation technology and major improvements have occurred, as evidenced by the fact that the average fuel economy of 1984 model automobiles is 88 percent better than 1973. Nevertheless, further technological improvements are possible in energy efficiency and in fuel flexibility. Our program focuses on highway because three fourths of petroleum use in transportation is by highway vehicles. The remaining 24 percent is used by other modes, including rail, air, and marine.

The FY 1985 budget in the transportation area requests \$51.1 million for operating expenses, capital equipment, and construction, which is \$10.0 million more than was requested in FY 1984. This amount is required to carry out a comprehensive program of research and development with a number of specific objectives. These are to: (a) support industry proof-of-concept testing of advanced engine technologies that have at least 30 percent improvement in fuel efficiency over comparable conventional engines, meet emission, safety, and noise standards, and have alternative fuels capability and competitive production costs; (b) develop technology for heavy duty diesel operation under uncooled and minimum friction conditions, having the potential of 35-40 percent fuel economy improvement over 1982 technology; (c) advance battery and propulsion system technology for competitive electric and hybrid

vehicles for passenger car, van, or light truck applications; (d) establish a fundamental ceramic and advanced materials technology base for the U.S. heat engine industry; and (e) develop a utilization-oriented data base on switching from petroleum to fuels made from oil shale, coal, and biomass.

I would now like to describe individually the Department's sub-program activities in the areas under your jurisdiction.

VEHICLE PROPULSION R&D

To achieve the objectives specified in P.L.95-238, the Automotive Propulsion Research and Development Act of 1978, of 30 percent improvement in fuel efficiency, meet emission standards and have alternative fuel capability, the two heat engines selected for development were the automotive gas turbine and automotive Stirling engine.

The Automotive Gas Turbine (AGT) project has been implemented through cost-shared proof-of-concept engine development contracts with two industry teams. A single-shaft configuration (AGT 101) is being developed by Garrett Corporation/Ford Motor Company and a two-shaft concept (AGT 100) by Allison Gas Turbine Operations/Pontiac Motor Division of General Motors. Application of high-temperature structural ceramic components has been seen as a critical technology barrier in both concepts because of the high operating

temperatures necessary to achieve efficiency goals. Advanced ceramic components are being integrated into test engines and dynamometer performance characterization of a fully ceramized high temperature configuration is anticipated in the FY 1985-FY 1986 time frame. During FY 1984 both contractor teams will complete performance testing of their engine designs and qualification tests of ceramic components. In FY 1985, one contractor team will continue the proof-of-concept engine development activity. The objective will be to integrate qualified ceramic components until a final configuration is reached and characterized. The second contractor team will continue efforts in ceramic component development only, utilizing existing test cells and engine builds for component evaluation. We have requested \$15 million to carry out these activities in FY 1985.

The Automotive Stirling Engine (ASE) project has focused on the development of a proof-of-concept engine with an industry team led by Mechanical Technology Incorporated (MTI), combined with United Stirling AB & Company of Sweden. Under this program, transfer of Stirling engine technology to the United States has now been accomplished. Over 4000 hours of performance testing has been completed on five MOD I experimental engines, and predicted performance goals for the design confirmed, including achievement of a maximum efficiency of 37 percent. An Industry Evaluation phase has been initiated

where MOD I engines will be loaned to the automotive industry for independent evaluation. The Industry Evaluation will be completed during FY 1984. During FY 1984, an Upgraded MOD I engine, which operates at higher temperatures and utilizes improved metal components, will be fully tested, and the design effort for the MOD II engine will be initiated along with component development and tests. By the end of FY 1984 sufficient technology development will have been accomplished and adequate test data will have been available from MOD I and Upgraded MOD I dynamometer testing and characterization, combined with a reference engine design upgraded with MOD II inputs and the results of the Industry Evaluation, to allow the automotive industry to use this data for making a rational assessment of the potential of Stirling engine technology for automotive propulsion systems in accordance with our "proof-of-concept" strategy. Hence, the Federal program goals have been accomplished and we are not requesting additional funds for Stirling engine R&D in FY 1985.

The Heavy Duty Transport Technology project has focused on establishing a technology data base for industry development of uncooled, minimum friction, adiabatic diesel engines. Elimination of the cooling system, with attendant high operating temperatures and recovery of the increased exhaust heat, offers the potential for greatly improved operational fuel economy of 35 to 40 percent compared with 1982 technology. The research strategy has been to concentrate on technology barriers

identified by industry and to plan development activities in such a way so as to support industry efforts to introduce individual components and concepts. During FY 1984, first phase efforts on a series of feasibility contracts involving thermal barrier coatings, structural ceramic components, ceramics joining, high temperature tribology, and advanced waste heat utilization concepts will be completed and the results evaluated. In FY 1985, the program will continue to support component development on the more promising ceramic components and coatings, solid lubricants and gas bearings, along with system integration and construction of single-cylinder test and evaluation equipment. Efforts in combustion and tribology research are sponsored by the Energy Conservation and Utilization Technologies (ECUT) Program in the Department's Office of Energy Systems Research complement and are coordinated with these activities. A total of \$2 million has been requested in FY 1985 for continuation of the adiabatic diesel project. .

Technology Assessment and Transfer activities of the Vehicle Propulsion R&D will be continued in FY 1985 to provide an ongoing assessment of related private sector developments and other Government sponsored programs to assure that maximum coordination with industry both for dissemination of program results and gathering of inputs on technology needs. \$1.5 million has been requested for these activities in FY 1985.

ELECTRIC AND HYBRID VEHICLE R&D

The goal of P.L.94-413, Electric and Hybrid Vehicle Research, Development and Demonstration Act of 1976, is to establish a Federal program of research and development of electric and hybrid vehicle technologies leading to the introduction of these vehicles into the Nation's transportation fleet.

The Electric and Hybrid Vehicle Program conducts R&D necessary to establish the technology base for advanced batteries and propulsion systems to the point of transfer to the automotive industry for further development.

Activities within the electric vehicle technology area involve development of experimental, aqueous, nonflow battery systems (lead-acid and nickel/iron), and flow battery systems (zinc/bromine). Improvements over existing lead-acid battery systems are needed to increase vehicle range, battery reliability and life and reduce battery costs. The intent of this development is to prove the capability of these battery systems to function properly in a realistic vehicle environment, including shock and vibration conditions and simulated driving profiles. Similar but non-duplicative activities associated with the sodium/sulfur battery have been initiated in the Office of Energy Systems Research. Integration between the various battery systems and the propulsion subsystems is underway to identify trade-off areas and potential areas of interaction. The primary battery/propulsion subsystem integration is being

conducted by Ford Motor Company. An advanced AC (alternating current) propulsion subsystem is being developed and integrated with three advanced batteries - sodium/sulfur, zinc/bromine, and tubular lead-acid - to assess the system trade-offs and performance associated with these powertrain configurations. It is the consensus of industry and government researchers that the AC propulsion system and advanced battery systems under development offers promising technology for a competitive electric passenger car.

A second battery/propulsion system integration is being initiated in FY 1984 for an advanced AC propulsion system that will have potential for van or light truck application. This advanced system will combine the AC power-train under development by the Eaton Corporation and the nickel/iron battery system developed by Eagle-Picher under previous DOE contracts. This program will be continued in FY 1985 to develop the technology and assess the performance, durability, and maintainability of a complete propulsion system for potential commercial vehicle application. Advanced technology activities involve assessment and development of systems and concepts that are early in their development cycles. Application related studies and testing are conducted to assess the viability of advanced battery, fuel cell, motor, and electronics designs for the unlimited range electric or hybrid vehicle application. In FY 1985, the vehicle application studies of the viability of advanced technologies will be completed.

The development of electric vehicle technology includes the testing and evaluation of actual on-the-road vehicles as well as laboratory testing of experimental batteries, components, and propulsion systems. Improved technology components such as nickel-zinc and gel cell batteries, microprocessor controlled battery management systems, and transmissions are being integrated into test vehicles by the Site Operators' User Task Force in FY 1984 and will be fleet tested in FY 1985. The Site Operator's User Task Force was formed by a group of fleet operators who have been using electric vehicles as part of their daily operations in a cooperative cost-shared program with the Department. Laboratory and dynamometer testing of emerging technologies will be continued in FY 1985. These include nickel-zinc, zinc-chlorine, tubular lead-acid and gel cell batteries, and a microprocessor-controlled battery system. \$6.8 million has been requested for the Electric and Hybrid Vehicle Program activities in FY 1985.

ADVANCED MATERIALS DEVELOPMENT

The Advanced Materials Development Program is a fundamental component of all transportation R&D activities. In high performance energy conversion systems, and in particular in advanced transportation engines, operation at high temperatures in corrosive environments is a key requirement for obtaining substantially improved efficiencies. A critical need is the development of ceramic or ceramic composite components which can withstand these operational characteristics. Although the

advanced engine projects are providing the required focus to prove the feasibility of ceramic components, they have also demonstrated that a parallel basic ceramics research effort is necessary for future development of reliable and reproducible ceramic parts. The goal of the Advanced Materials Development program, therefore, is to establish a technology base in ceramics and ceramic composites. Research will be conducted into ceramic materials and processing, design methodology, acquisition of technical data, and test of materials performance. Activities to date have resulted in the development of a long-range research plan based on a comprehensive assessment of industry requirements, the establishment of a common technical agenda with other Government agencies and laboratories; the organization of a formal interagency and industry coordinating committee to review research efforts and results; and the initiation of specific research efforts identified in the plan, including time-temperature ceramic properties evaluation, transformation-toughened ceramics characterization, fiber-reinforced ceramic composites, and ceramic coatings. In FY 1985 research activities will be expanded to include development of improved powders, high temperature property determination of ceramic composites, ceramic to ceramic joining, non-destructive evaluation of green-state ceramics, statistical concepts for design methodology, three dimensional modelling, and processing, characterization, and densification of green-state ceramics. Continued coordination will be maintained with both government and industry laboratories, and industry and university

fellowships will be instituted to strengthen feedback and maximize technology transfer. The advanced heat engine projects will continue to serve as industry test and evaluation sources. In accordance with the long-range research plan, we have requested \$7.0 million for the Advanced Materials Development Program in FY 1985.

The High Temperature Materials Laboratory (HTML) at Oak Ridge National Laboratory was initiated in FY 1983 to support advanced high temperature materials research in both government and industry. The HTML will have a unique capability with a broad multidisciplinary professional staff serving as a common focal point for industrial/university/government participation and having access to high-cost research equipment. During FY 1985 the construction contract will be finalized and site preparation, foundations, and major structural framing completed. Procurement specifications for major items of research equipment will be prepared. Building occupancy is scheduled for 1988. In FY 1985 we have requested \$10.6 million for the final increment to complete the building.

ALTERNATIVE FUELS

The Alternative Fuels Utilization Program has established a utilization oriented data base for alternative fuels in both contemporary and advanced heat engines. The approach has been to conduct systematic research on the fundamentals of alternative fuel use in both spark ignition and diesel engines, concentrating on nearer-term fuels first (alcohols) and expanding the data base in subsequent stages to include

synthetic fuels and advanced engines. During FY 1984 the utilization data base for alcohol fuels will essentially be completed and a capability for producing standard synthetic test fuels will become available for industry and scientific investigators. In FY 1985, basic fuel/engine performance/emissions investigations will be conducted to identify and provide an understanding of engine problems associated with the use of synthetic fuels and the alternative fuels utilization data base will be expanded to include the results of the investigations. Work will be continued on methane utilization with primary emphasis on diesel engine data. A total of \$1.5 million has been requested in FY 1985 for this work.

PROGRAM DIRECTION

To provide the overall program direction of the transportation program including the development of the strategy, plans and resource requirements, and integrated program management, we are requesting \$1,952,000 in FY 1985.

CAPITAL EQUIPMENT

Specific laboratory equipment has been identified that will be needed to support the research activities of the advanced materials development program and the electric vehicle program. The specific laboratory equipment includes a ceramics injection molding unit, ceramic materials hot isostatic press used to densify ceramic materials under high pressure and temperature, and high temperature crack growth test instrumentation. The

laboratory testing of electric vehicle technology at the newly established electric vehicle test facility at the Idaho National Engineering Laboratory will require automated cycling equipment to simulate driving conditions and electric vehicle test instrumentation. We are requesting \$3,000,000 for capital equipment for these purposes.

SUMMARY

In summary, the activities of the Department's transportation program cover a broad spectrum of projects structured to reduce energy consumption and petroleum dependence in the transportation end-use sector. Although the program is focused on the transportation sector, the technologies under development for high temperature ceramic materials, gas turbine and Stirling heat engines, batteries, and control systems can be effectively used in many other areas as well as the mobile application.

That concludes my testimony, Mr. Chairman, and I thank you for the opportunity to appear before you today.

**FISCAL YEAR 1985 DEPARTMENT OF ENERGY
AUTHORIZATION
(Transportation Programs)**

WEDNESDAY, FEBRUARY 22, 1984

**HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SUBCOMMITTEE ON TRANSPORTATION,
AVIATION AND MATERIALS,
Washington, D.C.**

The subcommittee met, pursuant to recess, at 10:07 a.m., in room 2325, Rayburn House Office Building, Hon. Dan Glickman (chairman of the subcommittee) presiding.

Present: Representatives Glickman and Boehlert.

Mr. GLICKMAN. Why don't we begin, if possible, and start the hearing this morning. Today the subcommittee will conclude its review of the Department of Energy's fiscal year 1985 budget request for transportation programs.

Yesterday we heard from the Department of Energy, and today we will hear from some of the contractors who are participating in the program, along with other interested parties.

As I said yesterday, we must be mindful of the long-term needs for conservation. I think it would be a tragedy of the first order if we were forced into a war to protect our Middle East oil sources because we hadn't invested a few dollars to find alternatives to that oil. And while today things may look fine, as I noted yesterday, our ships are in the vicinity of the Straits of Hormuz to protect against a potential Iranian-Iraqi act of madness in that part of the world. And so we have not lost sight of the fact, or shouldn't have lost sight of the fact, that there is a problem.

At the same time, we do have a budget problem in America today. We do not have to approve preexisting contracts just because they have been authorized and appropriated over the years. There must be compelling justification for those to be continued, because of the nature of the fiscal crisis we find ourselves in, and there must be some sort of an effort to see if some companies who have perhaps deeper pockets than others might find the capability to provide some support in these programs themselves.

So we are appreciative of the fact that you have come here to testify today, and now I would like to recognize my colleague from New York.

Mr. BOEHLERT. Let's proceed.

Mr. GLICKMAN. Let's proceed. I might say to the witnesses that I have personally a little bit of a time bind today, so I would appreci-

ate to the extent that you accelerate your testimony as much as you possibly can. Your entire statements will appear in the record. Thank you very much.

Our first witness is Mr. Noel Nightingale, program manager, automotive Stirling engine development program of Mechanical Technology Inc.

It is a pleasure to have you here. Why don't you proceed.

STATEMENT OF NOEL NIGHTINGALE, PROGRAM MANAGER, AUTOMOTIVE STIRLING ENGINE DEVELOPMENT PROGRAM, MECHANICAL TECHNOLOGY, INC., ACCOMPANIED BY EDWARD S. WRIGHT, MANAGER, GOVERNMENT PRODUCTS, AND VICE PRESIDENT, JOHN DEERE TECHNOLOGIES INTERNATIONAL, INC.; DEERE & CO., MOLINE, ILL.; AND BRUCE GOLDWATER, GENERAL MANAGER, STIRLING ENGINE SYSTEMS DIVISION, MECHANICAL TECHNOLOGIES, INC., LATHAM, N.Y.

Mr. NIGHTINGALE. Thank you, Mr. Chairman.

Accompanying me this morning is Mr. Bruce Goldwater, on my right, the general manager of the Stirling Engine Systems Division at MTI; and on my left, Mr. Ed Wright, the manager of government products of the John Deere Co. And I shall be referring to some aspects of the program in which Mr. Wright is involved with us now.

I have a written testimony, and as you stated, I would like to have that entered into the record officially. I have a set of viewgraphs now which I would like to go over which represent a synopsis of my written testimony.

I think it's important to recognize a little bit on the background of the program, of course, the Public Law 95-238, asking the Department of Energy to develop alternative power units for the automotive application. That program is a project managed out of the NASA-Lewis Research Center in Cleveland, Ohio. MTI is the prime contractor and a major subcontractor is United Stirling of Sweden, where at the beginning of the program the Stirling engine technology resided. And that will be becoming an issue in my testimony later.

We have other subcontractors as well.

The goals, I think, are worth recalling, not only to develop the Stirling engine for the automotive application but to transfer Stirling engine technology to the United States. The objectives which were, in fact, discussed to some detail yesterday are important. The first one, of course, is a 30-percent better fuel economy over a comparable spark ignition engine, and the emission goals which would match the 1985 Federal standards.

Alternative fuels, costs, noise, environmental issues are also objectives established for the program.

The logic of the program, of course, was to develop two engines in a series within the program; first of all, the Mod I and then the Mod II. I believe that that logic still applies and still can be followed to meet these goals and objectives of the program.

OK. I think I would like now to address some of the benefits of the program as we see them. First of all, I think that Congress choice to apply the Stirling engine to the automotive application

was indeed a correct one. I think that the level of technology required for the automotive application is indeed the highest. It requires high specific powers, low specific weights, the inverse. Difficult cost goals, packaging goals.

This slide (fig. 1) tends to give you a feel for some of the spinoff technologies or applications that can come as a result of the technologies developed in this program. But we still feel that the automotive application is indeed the prime importance.

Since a year ago or 2 years ago, there has been a great deal of activity surrounding the ASE program and the advances that we have made. Of course, immediately the industry test and evaluation program which we are conducting along with the General Motors, John Deere people, and Cummins, we already know that commercialized efforts are ongoing within the United States in the solar application and the agricultural irrigation area. There is movement afoot now in the generator set application. And of course, just recently, Stirling engines are being looked at seriously for space application.

We know that there are foreign activities in Japan, China, Germany, India for various uses of this technology.

So I think that not only in the automotive sphere but in these other spinoff technologies, there is a core technology which will benefit the Nation as far as jobs, independence during petroleum crises, which may happen quite easily again, the environmental issue; and it will provide a basis from which the United States can maintain a market leadership.

The automotive Stirling engine program has given that capability to us. The technology is ahead of anybody else in the world. And I think that it's important to maintain that leadership.

Of course, primary in the objectives of this program was the conservation of the natural resources, and I think that the performance of the engine to date demonstrates that potential.

I am going to take a few minutes now to highlight for you a few of the top accomplishments within the program specifically during the past 12 months.

First of all, at your direction, we have completed the Mod II preliminary design. And in fact, on the table in front of you is a casting, the wax casting, made by a vendor in Wisconsin. It is the Mod II V-block. It is used—it is made out of wax right now because it's using the tooling to allow us to check the design of that preliminary Mod II design. It will be poured in metal within the next 4 weeks.

So we are moving along as you have asked us in 1984 to follow up the final design and the procurement of the Mod II engine.

The next slide (fig. 3) is simply to give you an idea of the difference between the Mod II and the Mod I. On your right is the Mod II. On your left is the Mod I.

The important point here is that for the same power, improved efficiency, we have reduced the size of the engine design and allowed us to be competitive in terms of specific power, cost, and performance.

We are also in the throes of moving on with the industrial test and evaluation program. This next slide shows an upgraded Mod I installed in a vehicle compartment.

This vehicle is ready right now. It will be road-tested—it has been road-tested and will be road-tested again out in Detroit. And it is the first engine and the first vehicle, and it will be going out to General Motors for their test and evaluation, independent, at their own cost, according to their own test plan, and according to their own time schedule.

Over the past 12 months we have accomplished a great deal of engine testing that has demonstrated the life, the reliability, and the durability of a Stirling engine.

You can note from the slope of this curve (fig. 5) that we have accomplished way over 3,000 hours in the last 12 months. And this is ever so important to the industry people when we talk to them, because they're concerned with reliability, life, and durability. In fact, in this curve is one engine which ran for a thousand hours on endurance. 100,000 miles is approximately equivalent to 3,500 hours. That gives you a little guide.

This is a picture of the upgraded Mod I in the MTI test cell (fig. 7). During the past 12 months we redesigned the Mod I to put in some of the technologies which we want to design into the Mod II; namely, small size while maintaining performance and power.

This engine is 100 pounds lighter than the original Mod I.

This gives you a size, size scale of the difference between the Mod I on the left, and the upgraded Mod I on the right. It's the upgraded Mod I on the right that is being delivered to industry for their evaluation.

The last area that I would like to comment about our performance in 1983 was our involvement now with the ceramic industry. We have approached the Porcelain Co., located in Colorado, to begin the design and development of a ceramic preheater (figure 8).

I have a sample of it here, and this is a ceramic component which was developed originally for gas turbine. It is not directly applicable to us, because we need to have lightweight, low cost. And we are working with the Porcelain people in developing the Stirling engine type of technology.

Ceramics applied to Stirling engine is not as straightforward as some people might believe.

Now I would like to comment on where I think we are relative to the overall goals of the program. First of all, the goals being performance related, and second, the transfer of technology.

A great deal of discussion was conducted yesterday about the vehicle mileage. This plot (fig. 9) shows the mileage relative to the IC mileage in a comparable car that we are using within the program. The Mod-I, we were very, very pleased with, although it was about equal to the IC. The upgraded Mod-I, because of its slightly higher efficiency, allowed it to get approximately a 20- to 18-percent mileage improvement over the IC. And that is a logical stepping-stone, logical increase to our ultimate Mod-II goal of 30 percent better than the IC. So we are well on our way in the progress of the performance of the engine.

Specific weight is a big subject relative to the automotive application. The Mod-I and the upgraded Mod-I were well above those offered by conventional engines, although they offered a great improvement over the technology that we inherited at the beginning

of the program. The Mod-II will be—have a specific weight competitive with the diesel.

Manufacturing costs, I think, is one of the key issues. There is no way that the Mod-I or the upgraded Mod-I could be a production-type engine. The cost is just prohibitively high. The Mod-II, as evidenced by this V-block casting, incorporates not only Stirling engine technology but automotive practice technology, and we are trying to meld those together toward this cost goal to be competitive with conventional engines.

Let me address technology transfer for a moment because I think there tends to be a misunderstanding that the job is complete, that the Mod-I completed everything and why isn't industry picking this up? The fact is that technology transfer is not complete. First of all, the Mod-I was designed and analyzed in Sweden. The Mod-II is going to be designed and analyzed at MTI. And that is a strong distinction.

So the curve on your left (fig. 10) indicates subjectively, I admit, the percent of technology transfer accomplished within the Mod-I in the design and analysis area and how much more we're going to accomplish in the Mod-II program.

Certainly, in the manufacture of engines we did a great deal in Mod-I. We set up about 30 vendors in the United States, and we almost accomplished the full technology transfer of that area. In the case of assembly and test, I believe that full knowledge has been transferred indeed to the United States. And in fact, we are, through the ITEP program with John Deere and General Motors, involved in transferring some of the assembly and test technology transfer to them under the ITEP.

I think if we look at the level of industry interest over the past year, one would agree that it has been negative. About 4 or 5 years ago it was negative, and rightly so. The engines were very, very heavy, certainly not applicable to the automotive application. However, industry is not interested in paper designs. Industry is not interested in projections. They're interested in hardware and engine data. And when the Mod I jumped on the scene, as shown on this graph (fig. 13), we noticed an improvement and an increase in the interest from industry. And as shown on the far right of the graph, we believe that interest will continue to grow when the Mod-II is shown—can you move it a little bit, Bruce; yes—in 1985, late 1985, when the Mod-II hits the scene. We feel that that interest will generate into an earnest involvement in automotive development of Stirling engines.

I am going to address just for a moment what we see in the future of the ASE program. Certainly, the ITEP program, which will be completed in fiscal year 1984, involving General Motors, John Deere, and Cummins, will offer an opportunity for industry to evaluate where the technology is and whether it can be applied to the automotive application.

Via the Mod-II design, of course, we will have an opportunity to demonstrate the program objectives and meet those objectives both in fuel economy, lower specific weight, cost, and complete the technology transfer goal, as I had explained on an earlier chart.

The question comes up, What happens in post-Mod-II? We would see possibly a cost-sharing program with industry. Certainly, some

technology development supported by the Government, as you are doing now in gas turbines and diesel. And perhaps even some spin-off development of these other applications.

I think that any post-Mod-II development effort should not be void of involvement from the ceramic side nor from the alternative fuel side. I think those are two important areas that should go along with a post-Mod-II-type development.

I apologize for all the words on this slide, but I did want to make sure that I did not miss the points of the conclusions, which are in the written testimony; basically four: The Stirling engine can meet the original goals of title III. The design and development of the Mod-II engine will complete the transfer of Stirling engine technology to the United States. The technology developed under the program provides U.S. industry with a technology base on which it can maintain its leadership in domestic and world markets. There are two subtleties to this: The Stirling engine technology required for the automotive application are the most stringent, as I said earlier; and I think that was a wise choice.

In terms of the foreign competition, we know there is a great deal of activity going on. The United States has the leadership in Stirling engine technology, and I think this program offers the vehicle by which we can maintain that leadership.

And last, the Stirling engine technology is in its infant stages. As I point out in my written testimony, there are demonstrations, there are prototypes, there are experimental, and there are preproduction and production phases which I think this technology still has to go through.

So, in my last slide, Mr. Chairman, is that I would strongly recommend that the ASE program be authorized to continue through the completion of the Mod II engine development program.

And that concludes my remarks, and I am certainly open now to any questions you may have.

Mr. GLICKMAN. Thank you, Mr. Nightingale.

Completion of Mod II would require how many additional years, and how much money?

Mr. NIGHTINGALE. We—when I try to answer that question, Mr. Chairman, of course, I am trying to see it from your side. You are looking at the total appropriation, and I think I would have to agree with Mr. Collins' comments yesterday in which he quoted 3 years and about \$42 million.

Mr. GLICKMAN. Three more years?

Mr. NIGHTINGALE. Yes. 1985, 1986, 1987.

Mr. GLICKMAN. And approximately—

Mr. NIGHTINGALE. Forty-two, at the appropriation level.

Mr. GLICKMAN. \$42 million?

Mr. NIGHTINGALE. Yes.

Mr. GLICKMAN. If the program is terminated at the end of fiscal year 1984, as the Department of Energy proposes, where will you be with respect to meeting the goals identified in the law?

Mr. NIGHTINGALE. In terms of the goals, the—first of all, the performance goals will not have been met, as I pointed out in some charts. The mileage; the emissions; the costs; the specific weight will all have fallen short of the goals. In terms of the technology

transfer, we would have fallen short there. We would not have had the design or the analysis or the full manufacturing capability.

Mr. GLICKMAN. What would be the role of Sweden in the Mod II program if it's terminated?

Mr. NIGHTINGALE. Yes. The role of Sweden is very critical in the Mod II. They act as a design audit team, with their experience in everything. We use our design analysis, and they can audit that analysis and give us the benefit of their years of experience in that field.

Mr. GLICKMAN. I want to know specifically what, let's say, the Japanese and the Europeans are doing in this area and how much money they're spending in Stirling technology.

Mr. NIGHTINGALE. In terms of the Japanese area, I'll turn to Mr. Goldwater, who has in fact toured over there. I think I can comment, though, on the German aspect first, and then I will turn it over to Bruce.

In Germany we know that Daimler-Benz bought three Stirling engines. We estimate that that was somewhere between \$1.5 to \$2 million commitment on their part over the last 3 years. They have been testing it in a light-duty van. They have approached United Stirling now to see if they could have a Mod I to use in that duty—light-duty van application. So that we know that they are willing to spend their own resources and time to look at this valuable technology.

I think I will turn the first part of the question over to Bruce to comment on Japan.

Mr. GOLDWATER. Mr. Chairman, the Japanese information that we have is primarily in the record from the government side. They're spending somewhere on the order of \$30 million over about a 4- or 5-year period. But that is only a small percentage of the dollars that are being spent, as we determined. It seems that almost every private company in the manufacture of engines, and even some companies that are in other types of application industries, are spending money on their own in addition to the amount of money that the government is putting forward.

Mr. GLICKMAN. Other than yourself, is there any research dollars flowing to Stirling technology in this country privately?

Mr. NIGHTINGALE. Yes. Yes, I know of one company in Nebraska who is developing a Stirling engine for agricultural irrigation.

Mr. GLICKMAN. Which company is that?

Mr. NIGHTINGALE. Belmont.

Mr. GLICKMAN. Pardon?

Mr. NIGHTINGALE. Belmont. And they have put all of their own money into the development. And in fact, one of the spinoffs is that they ran into seals problems, and they came to us, and we worked with them on the technology that we had learned on seals to help solve their problems.

Mr. GLICKMAN. The Department of Energy says that the Stirling proof of concept has now been demonstrated and it's ready for a decision by industry. That was the same thing that they said last year. How do you respond to that?

Mr. NIGHTINGALE. I think realistically that it is not ready for industry to accept. The Mod I, we were very proud of our accomplishments on the Mod I. We came from a situation in which it wasn't

even thinkable, had no potential for the automotive application. I think the Mod I raised the question, indeed, "Is the potential there," because of the excellent performance that it had and the marked improvements in specific weight and so forth.

But I think that industry sees it as being in its infant stages and that there is still a great deal of research and development required to bring it to the point of preproduction phase or production phase.

And so to answer your question specifically, no, I don't, do not think it's ready for industry.

Mr. GLICKMAN. Mr. Boehlert.

Mr. BOEHLERT. Mr. Nightingale, are you on schedule thus far?

Mr. NIGHTINGALE. Yes, we are.

Mr. BOEHLERT. And how about, are you within budget?

Mr. NIGHTINGALE. Yes, we are. We always have been, Mr. Boehlert.

Mr. BOEHLERT. All right. What does NASA-Lewis say to you about your work? How do they characterize that?

Mr. NIGHTINGALE. Yes. It's not very often you can have a program like we have with a report card. We work under what we call an "award fee contract" with NASA, and each year we are evaluated in four important areas: program management; technology transfer; accomplishments. And this year, as in the past 2 years, we have been rated outstanding in all four categories and outstanding in the conduct of the program overall, which is the highest rating they can give us.

Mr. BOEHLERT. You're on schedule. You're within budget.

Mr. NIGHTINGALE. Yes.

Mr. BOEHLERT. And your performance is outstanding.

Mr. NIGHTINGALE. According to NASA.

Mr. BOEHLERT. Well, you were here yesterday, I believe, to hear Mr. Collins.

Mr. NIGHTINGALE. Yes, a little bit, Mr. Boehlert, yes.

Mr. BOEHLERT. He sort of said, "It's a success. Let's go on to other things and forget about it." But you're saying today to me, among other things, that there's no way we can continue or go to the manufacturing stage with the Mod I and be cost efficient. So that if I am hearing you correctly, you're arguing very forcefully that we go to Mod II.

Mr. NIGHTINGALE. Yes. I am, Mr. Boehlert, yes.

Mr. BOEHLERT. And 3 years and \$42 million, is that what you're saying?

Mr. NIGHTINGALE. Yes.

Mr. BOEHLERT. So you agree with DOE on that?

Mr. NIGHTINGALE. Yes, yes, I do.

Mr. BOEHLERT. Where do you think there's a breakdown? Is it DOE that's less than enamored with proceeding, or is it OMB? Do you have any feel for this?

Mr. NIGHTINGALE. Yes, I think so. I think that what happens is that success gets a little bit blown out of proportion. And as I said, the Mod I was an incredible step forward in the technology, as perceived in the earlier Stirling engine models. And so it kind of gets blown out of proportion that, "Well, why wouldn't industry be interested in this incredible step?" But we're really still back in the

Model-T stages, and there's a great deal of work that yet has to be done.

So I think that there is this expectation that once you make this one step, that then the ballgame is over. And it isn't. There is still a great deal of work to be done. And I think industry, being of a very practical mind—and perhaps Mr. Wright wants to expand on my point—but I think they see it as a glimmer of hope, assessing the potential of gain from the technical level, but recognizing the practicalities involved.

Mr. BOEHLERT. Well, I think perhaps a couple of years ago the reaction from industry was a muffled yawn, probably, but even Undersecretary Collins yesterday conceded there is a great deal more interest from industry. I am not certain if the chairman posed the question, but what is industry spending? GM, the auto industry, Deere, are they putting any dollars into this program?

Mr. NIGHTINGALE. Well, I think I will try to answer that in two parts. First of all, I will give you my opinion, and I think I will ask Ed perhaps to express his opinion.

In terms of money spent, we know that General Motors is committing their own resources. They haven't paid to get into the program, but they have had to set aside valuable resources, people, facilities, time, to conduct the tests. As I tried to qualify, the Daimler-Benz people—and I think Daimler-Benz represents a—they definitely represent the automotive industry, there's no question about that—have put a great deal more into it. And I tried to quantify that at about a \$1.5 million to \$2 million. I think that's about right.

Perhaps, Ed, you'd like to expand on that.

Mr. WRIGHT. Well, the commitment on the part of John Deere is not to design the Stirling engine, as I am sure you are aware. We are participating in the ITEP program, and that does involve a fairly significant commitment in terms of resources, people, test equipment, evaluation. And we don't have very deep pockets, so I think we do think that in spite of the financial constraints we're under now it still is worth our while to stay on top of this technology.

Mr. BOEHLERT. Mr. Nightingale, I am a relative newcomer here. I think you recognize that. How much have we spent, and how long have we been involved?

Mr. NIGHTINGALE. We have spent—at the end of fiscal year 1984, I think that's the best number to give you——

Mr. BOEHLERT. Right.

Mr. NIGHTINGALE [continuing]. We will have spent about \$75 million.

Mr. BOEHLERT. \$75 million?

Mr. NIGHTINGALE. Yes. And we started in March 1978. So that's approximately 6 years.

Mr. BOEHLERT. So is it fair to say that if we walk away from it now, that \$75 million it really is——

Mr. NIGHTINGALE. I believe so, Mr. Boehlert, yes. I honestly believe so; that is, the technology that would be shelved. And the interest is increasing at such a rapid rate from not only the automotive industry but other industries, that I think it would be a foolish move to cut it off now.

Mr. BOEHLERT. Just one last observation. The ranking member, minority member of the subcommittee, is not here today. I would suggest you spend some time with him.

Thank you.

Mr. NIGHTINGALE. Thank you.

Mr. GLICKMAN. Thank you, Mr. Nightingale, for your testimony.

Mr. NIGHTINGALE. Thank you, Mr. Chairman.

[The prepared statement of Mr. Nightingale follows:]

HEARINGS ON DOE TRANSPORTATION PROGRAMS

**Subcommittee on Transportation, Aviation, and Materials
Committee on Science and Technology
U.S. House of Representatives**

**Presented by: Noel P. Nightingale
Program Manager
Automotive Stirling Engine Development Program**

February 22, 1984



Noel P. Nightingale

Mr. Noel Nightingale is the Program Manager of the Automotive Stirling Engine Development Program. Mr. Nightingale is employed with the Stirling Engine Systems Division of Mechanical Technology Incorporated, Latham, New York, a high-technology research, development, and manufacturing company. He has been involved in the ASE Program since its inception in 1978 and has authored various papers on its progress. Prior to that, he was employed for more than twelve years with Pratt & Whitney Aircraft, a Division of United Technologies Corporation. During that period he undertook technical and managerial roles in the design, analysis, and development of military and commercial gas turbines and large (100 MW) ground power units. He also has management experience in multinational consortium programs and aircraft maintenance. Mr. Nightingale holds a Bachelor Degree in Mechanical Engineering from the University of Toronto and Master Degrees in Engineering Science and Business Administration from Rensselaer Polytechnic Institute.

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TESTIMONY ON THE AUTOMOTIVE STIRLING ENGINE PROGRAM**before****Subcommittee on Transportation, Aviation, and Materials****Committee on Science and Technology****U.S. House of Representatives**

Mr. Chairman, members of the subcommittee, my name is Noel Nightingale, and I am the program manager of the Automotive Stirling Engine (ASE) Development Program funded and managed by the Department of Energy (DOE). The NASA-Lewis Research Center located in Cleveland, Ohio, is responsible for overall project management. The program is being conducted within the Stirling Engine Systems Division (SESD) of Mechanical Technology Incorporated (MTI). MTI is a high-technology research, development, and manufacturing company located primarily in the state of New York, with wholly owned subsidiaries in Michigan and California. The SESD engages approximately 120 people in the development of Stirling engines for a variety of applications. This team, primarily professionals, was formed by MTI in response to the national need for an advanced energy-efficient technology, in this case, the Stirling engine.

Mr. Chairman, MTI appreciates the opportunity to appear before this subcommittee. My testimony today consists of a status report on the ASE development program, which has two basic goals: 1) to develop the Stirling engine for an automotive application, and 2) to transfer Stirling engine technology to the United States. I shall report on our status in the pursuit of these goals. In addition, I shall comment on our expanding involvement with several industrial companies who are becoming interested in understanding and using Stirling engine technology, on foreign activities in the Stirling engine field and their possible threat to our industry base, and finally, on the development activities that may be required after the completion of the current ASE program, as well as on specific conclusions and recommendations regarding Stirling technology. Any figures or tables referred to in the text are included, for your convenience, in numerical order at the end of this testimony.

BACKGROUND

In Section 302(b) of Public Law 95-238, the United States Congress charged the DOE with initiating programs leading to the development of advanced automotive propulsion systems. DOE selected two basic engine cycles: the gas turbine and Stirling. The Stirling engine was selected because of its intrinsic capability to provide high-cycle efficiency; i.e., when installed in an automobile, the Stirling engine can attain a higher fuel economy than that of conventional power systems. Further, since the engine uses a continuously burning external combustion system, it is capable of using a variety of liquid fuels while maintaining low emission levels.

MTI is the prime contractor on the Stirling engine program, with United Stirling of Sweden (USAB) as a major subcontractor. USAB not only provides a strong background in Stirling engine technology but also offers highly experienced personnel, crucial in the support of all aspects of the program. Their participation has served to ensure the transfer of the Stirling engine technology and know-how, which resided with USAB at the beginning of the program, to the United States. This technology transfer, one of the program goals, has evolved throughout the actual development of the automotive Stirling engine, the other program goal.

The logic originally set forth on the program was to develop two engine system generations in series. The Mod I was to be a new engine design, based on Stirling engine technology as it existed in Sweden at the beginning of the program (in 1978); the Mod I engine was, therefore, configured after engines developed in Sweden. The Mod II, on the other hand, was to be designed in the United States, and was to incorporate technology advancements made during the course of the ASE program.

The ASE program also has a number of specific objectives stemming from the public law. They are:

- A 30% improvement in fuel economy over a comparable production engine
- Operation within projected 1985 emissions standards ($\text{NO}_x \leq 0.4$, $\text{HC} \leq 0.41$, $\text{CO} \leq 3.4$ grams/mile, and particulates ≤ 0.2 gram/mile)
- Interchangeable operation on a variety of liquid fuels
- Reliability and life expectancy comparable to commercial engines

- Initial cost and life-cycle cost competitive with conventional engines
- Acceleration suitable for safety and consumer considerations
- Noise and safety characteristics meeting the 1984 Federal Standards

To achieve national acceptance, the automotive Stirling engine must be capable of being packaged in a small compartment, be able to provide sufficient power to propel a weighty vehicle, and still meet exacting performance criteria, such as acceleration from 0 to 60 mph in 15 seconds. The engine must be efficient over a wide range of power and speed settings, providing high fuel economy both in the stop-and-go-environment of city driving and in the constant-speed cruising of highway driving. It must not pollute, and it must be capable of using (in the future) alternative fuels. It must be inexpensive to manufacture and capable of being serviced (routine maintenance) by the general public. Finally, a Stirling vehicle must be capable of operation in hot and cold climates while providing the "operator" with a "cabin" environment that is comfortable in terms of temperature, humidity, noise, and vibration.

Although the time frame and magnitude of the ASE program have been altered by budget restrictions over the past three years, the conceptual design of the Mod II was completed in 1983 at the recommendation of this subcommittee; and further, it was this subcommittee's recommendation that the FY84 program include the design and hardware procurement of the Mod II engine. In order to meet the legislated goals in a timely fashion, FY85 will be one in which all Mod II engine hardware will be manufactured and preassembled for full engine system test and evaluation in FY86. Hence, our request for a FY85 appropriation is 17.5 million dollars, of which 14 million dollars is expected to be allocated directly to the MTI contract.

BENEFITS OF THE ASE PROGRAM

Congress's choice to develop the Stirling engine for the automotive application has, indeed, proven to be a correct decision. The level of technology development required for an automotive Stirling engine is very high and most difficult. Figure 1 depicts the level of technology associated with the automotive application compared to other Stirling applications. This assessment, although certainly subjective, does underline a key national benefit - that the ASE program will provide the United States with a core technology that has a host of

spin-off applications. This, in turn, will provide our nation with the capability not only to conserve energy in other crucial applications but also to maintain the technological leadership in those areas.

Providing the United States with this technology will place it in the forefront of leadership in other Stirling applications. Efforts in Stirling engine development are already being conducted in this country, as well as in foreign countries; Figure 2 is a summary of these activities. Immediately spinning off from MTI's ASE program is the Industry Test and Evaluation Program with General Motors, John Deere, and Cummins. Within the United States, the application of Stirling engine power to agricultural irrigation and solar energy generation is well in place and in the process of being commercialized. Further, the advantages of applying Stirling engines in space is now only being realized. And, lastly, the use of Stirling engines in generator sets is being evaluated by the military due to the engine's inherent low exhaust temperature and noise level, as well as its multi-fuel capability. However, foreign activity at Toyota (Japan) and Daimler-Benz (Germany) is also known to be occurring in the automotive field. At Daimler-Benz, for example, a light-duty van is being used to evaluate different engine systems. Also beyond the U.S., India is known to be assessing the Stirling engine for the automotive applications, and China is evaluating it for a variety of applications (due mainly to its multi-fuel capability).

These developments underscore the vast potential for jobs and for technological expansion offered by the Stirling engine. Through the introduction of Stirling technology into U.S. products, new jobs in manufacturing and services, as well as an increase in associated trade employment, will result. The multi-fuel capability of the Stirling engine will provide personal and national security in times of petroleum dislocation, and the Stirling engine will meet the emission standards defined by the Clean Air Act, thereby contributing to the national effort to upgrade our environment. The ASE also provides an advantage to improving our noise environment, as the noise level emitted from a Stirling engine is much less than that of conventional engines... the Mod I vehicle installation did not require a muffler because of the extremely low level of noise in the exhaust. Finally, the overall potential for conserving valuable fuel resources through the use of more efficient Stirling engines in automobiles and in other applications is immense. This potential has been clearly shown through results already published from the ASE program.

SUMMARY OF FY83 ACCOMPLISHMENTS

Major advances towards the ASE program goals have been made during the past year. Those major accomplishments include:

- Completion of Mod II Preliminary Design - The design of the Mod II engine has begun as has the procurement of long-lead hardware. The Mod II, as designed, incorporates new concepts and technology advancements directed toward meeting the stringent requirements of an automotive installation and application that were not totally achieved through the Mod I. These include small size (smaller size also provides cost benefits), light weight, and high specific power.

Figure 3 compares the smaller Mod II engine to that of the Mod I, and Figure 4 shows a wax model of the Mod II engine V-block. The V-block incorporates acquired Stirling engine technology with good automotive design practices. The wax model, poured by a vendor in Wisconsin, is used as a check for the accuracy of the design prior to its being poured in metal.

- Initiation of ITEP - Due to the foresight of congressional subcommittees, the Industry Test and Evaluation Program (ITEP) was initiated in 1983. ITEP is directed at providing engines to industry so that U.S. companies can evaluate and assess the applicability of Stirling engines. General Motors, John Deere and Cummins all signed formal agreements with NASA-Lewis to participate in this evaluation. The first ITEP engine was tested successfully and installed in a vehicle, which is currently being passed through a series of check-out tests, is on schedule, and should be delivered to General Motors in March 1984. This vehicle will undergo chassis dynamometer tests, cooling tunnel tests, and road driveability tests, all conducted by General Motors' engineers and technicians at their own site and at their own expense. A second engine is being prepared for assembly and will be delivered to the John Deere Company in July 1984, at which time the engine will be tested and evaluated in a test cell. Cummins' role in ITEP will be to keep abreast of the tests conducted at both sites, evaluate data, and, when appropriate, participate in engine tear-downs to inspect the condition of selected components.

- Accumulation of Mod I Engine Test Hours - During the past year, more than 3000 engine test hours have been accumulated on Mod I engines, bringing the total accumulated level to 4843 hours. This level of testing has helped to demonstrate the life, reliability, and durability of the Mod I Stirling engine, all of which are important to the automotive and engine manufacturing industries if Stirling engines are to be commercialized. Figure 5 shows the rapid increase in accumulated test hours over the past 12 months. It was during this time period that one engine was tested continuously for 1000 hours (3500 hours of testing is approximately equivalent to 100,000 miles of driving).
- Upgrade of Mod I Engines - During the past 12 months, two Mod I engines were retrofitted into an upgraded configuration (Upgraded Mod I). The upgraded engines provide a means of proving selected new technologies that have been designed into the more refined Mod II. The weight of the upgraded engine was reduced by 100 pounds through the use of lightweight materials and by reducing the diameter of specific components. As shown in Figure 6, the diameter of the outer shell of the Upgraded Mod I is considerably smaller than that of the Mod I. (Size reduction is a requirement for the Mod II). The Upgraded Mod I uses new iron-based materials, void of the strategic material cobalt used in the Mod I. These new materials provide a large cost reduction and are planned for incorporation in the Mod II engine design. Figure 7 is a photograph of an Upgraded Mod I engine installed in MTI's test cell.
- Development Work on Ceramics Materials - A portion of the technology advancements made during the program have demonstrated that ceramics can be used in Stirling engines. Therefore, the Coors Porcelain Company, located in Colorado, was subcontracted to design and manufacture ceramic preheater segments for the Mod II. As shown in Figure 8, the subject preheater is a heat exchanger in which hot exhaust gases exiting from the combustion chamber transfer heat energy to cool incoming air. The use of inexpensive ceramics in this area would be a major development since the effectiveness of a preheater in exchanging the heat energy is a major contributor to the high efficiency of a Stirling engine.

PROGRESS TOWARD PROGRAM GOALS

The program goals are specific, and progress toward them has been steady and positive. One goal is that the ASE demonstrate fuel economy with mileage 30% better than that of a spark-ignition engine installed in the same vehicle. Figure 9 shows the progress made toward this goal during the course of the program. Although the Mod I did demonstrate mileage equal to or slightly better than that of a spark-ignition engine, it is predicted that the Upgraded Mod I will show an improvement of approximately 20%, and that the Mod II engine, with its improved technologies, will meet the projected program goal of 30%. Actual engine test data should confirm this prediction in early 1986.

The Mod I has demonstrated the potential of Stirling engines to meet stringent goals regarding emissions and particulate levels. This is possible due to the inherently clean exhaust emitted from the Stirling engine's continuously burning combustion system. The following table summarizes the emission levels measured on the Mod I engine and predicted for the Mod II engine when installed in a vehicle during a Constant Volume Sampling (CVS) transient test similar to those conducted by the Environmental Protection Agency (EPA).

Emission Levels (gram/mile)			
	Goal	Mod I (Measured)	Mod II (Predicted)
CO	3.4	3.3	3.3
HC	0.41	0.25	0.25
NO _x	0.40	0.90	0.4
Particulates	0.2	0.087	0.087

In general, the emissions goals established for the program have been met except for NO_x, and it is projected that the Mod II engine will meet this requirement.

The analytical codes developed at USAB could not be transferred to the U.S. due to licensing restrictions; therefore, simultaneous to the gaining of knowledge and understanding of Stirling engine technology, MTI was required to construct and develop its own analytical codes. In addition, in order to predict the

stress levels and, therefore, the life of the design, it was necessary to obtain sufficient data from actual engine tests to provide confidence in the predictions of the developed codes. Therefore, a particularly impressive achievement to date in the program is the fact that we have acquired sufficient knowledge in Stirling engine technology to develop and verify the required analytical codes using, largely, our own funds.

THE STATUS OF TECHNOLOGY TRANSFER

In evaluating and measuring the progress of technology transfer, one quickly becomes aware of the fact that technology transfer is a multifaceted process. The functions attributed to understanding Stirling engine technology and, thus, involved in an effective technology transfer are design, analysis, manufacturing, assembly and test. Design involves understanding the methodology and subtleties peculiar to the design of Stirling engines. MTI now has a full staff of designers working on the Mod II design. Analysis includes not only understanding the Stirling thermodynamic characteristics but also knowing the tools or computer codes to execute the analysis. The codes were, as stated, not transferred, but a significant understanding of the technology has been acquired so that we were able to develop these tools. The ability to manufacture Stirling engine components was one of the first areas to be understood. Early in the program a vendor base of more than 30 individual companies was established to manufacture, fabricate, and assemble Stirling engine hardware in the United States. One Mod I engine and both ITEP engines were manufactured using this vendor base, therefore establishing the success of this portion of the technology transfer. The ability to assemble and test Stirling engines also was quickly transferred during the early Mod I engine test program. In fact, it is this particular aspect of Stirling technology that MTI will now transfer to industry in the course of the Industrial Test and Evaluation Program.

Another aspect of technology transfer is having the tools and resources in place to take advantage of the knowledge gained during the transfer process and to be able to apply that knowledge. As mentioned previously, an analytical code is one of those tools; so are test facilities and personnel. MTI has in place one engine test cell and six component test rigs. MTI also has in place a trained staff of engineers and technicians ready to transfer Stirling engine know-how to U.S. industry, in much the same manner as is currently happening in the ITEP.

In summary, then, the process of transferring Stirling engine technology to the United States has been on-going since the beginning of the program, with portions of it already completed. In fact, portions of it are being passed along to U.S. industry, within the context of the ITEP. Figure 10 depicts the current status of technology transfer. The Mod I was designed and analyzed at USAB; the Mod II is being designed at MTI. The manufacturing function was transferred mainly during the course of the Mod I engine program; there were, however, certain components made outside the United States to avoid the duplication of expensive tooling. For the Mod II, these components and their tooling will be manufactured in the U.S. Finally, the knowledge and know-how to assemble and test engines and components were transferred during the Mod I program, and it is this phase of the technology which will be partially transferred to industry under ITEP. As the figure shows, the Mod II program will complete the transfer of all aspects of Stirling technology.

INDUSTRY INTEREST

No disagreement exists regarding the fact that implementing a new engine technology, such as Stirling, into the automotive industry is extremely difficult. To recognize this difficulty requires the understanding of the implementation process: it begins at the research level with technical people agreeing on the potential of the technology, and progresses through a demonstration phase, an experimental phase, a prototype phase, a preproduction phase and, finally, to production.

Earlier Stirling designs did not address the automotive application and, consequently, were large, bulky engines with very low specific power, unreliable systems, short life, and high cost. The general opinion, understandably, was negative in terms of the application of Stirling engines to the automobile. With the arrival of the Mod I, an actual engine designed for automotive use, the general opinion began to change, for the Mod I represented enough of an improvement in critical areas to justify a review. This review will be conducted via the ITEP with the expectation that the potential for Stirling applications will be confirmed.

Unfortunately, the Mod I does not go far enough. It does not satisfactorily demonstrate the potential of the Stirling engine to meet all system requirements for the automotive application. These requirements, as a minimum, are: high efficiency, low emissions, low cost, life, reliability, durability, low noise, transient capability, and high specific power. The ITEP evaluation will have to look toward the Mod II predictions when final assessments are made. Figure 11 shows the projected lower cost of the Mod II, and Figure 12 shows the lower specific weight of the Mod II. Both are critical factors in the ultimate review of the potential for success in the marketplace.

Figure 13 shows that the technical community began to take an active interest in Stirling engines once the Mod I data was released, and it is anticipated that the Mod II data will lead to a consensus of opinion, within the same community, that the full potential of the Stirling engine can be realized.

POST MOD II

As stated previously, the Mod II engine is expected to foster agreement among industry engineers and scientists regarding the Stirling engine's potential to meet the requirements of the automotive application. There are, however, many phases through which that technology must pass before reaching actual production. In the Post Mod II time frame, industry would be expected to play a strong and active role in engine commercialization. Because of the inherent risks involved, Government should consider cost-sharing programs wherein the technology would not only be further advanced, but also the Government would provide a continuing technology enhancement base as it is doing in the diesel and turbine areas. Although the ASE program, so far, has produced dramatic successes, it is clear that, although the technology remains young, great gains may be made in the future for a variety of applications. Therefore, the technology of Stirling engines should not stop with the Mod II. Any activity beyond Mod II should also include advanced technology development in the use of ceramics for the Stirling engine. These developments, it should be mentioned, would go beyond the ceramic applications currently being developed for other engine systems. Lastly, the development of alternative fuels should parallel and be interwoven into any Stirling engine development activity.

CONCLUSIONS

Mr. Chairman, I would like to summarize the status of the ASE program by stating the following conclusions:

1. The Stirling engine can meet the original goals of Title III of Public Law 95-238.
2. The design and development of the Mod II engine will complete the transfer of Stirling engine technology to the U.S.
3. The technologies developed under the ASE program provide U.S. industry with a technological base from which it can maintain its leadership in domestic and world markets.
 - a. The Stirling engine technologies required for the automotive application are the most stringent; once fully developed, they provide the potential for numerous spin-off applications for U.S. industry.
 - b. The attention and support that Stirling engine technology is receiving by foreign governments and private companies provide a threat to the economic leadership of the U.S. in that a broad array of foreign-born energy-efficient products may appear on our market unless we capitalize on our current technological advantage.
4. Stirling engine technology is in its infant stages, and industry, although interested and watchful of its development, is still not prepared to assume any development risks.

RECOMMENDATIONS

With the foregoing conclusions in mind, Mr. Charman, I would like to recommend that the ASE program be authorized to continue through to the completion of the Mod II engine development program. The numerous advances realized to date and

those yet to be realized will be lost unless the Federal Government is willing to give continued support to this program. The Mod II will not only provide an acceptable alternative to the spark-ignition engine, it will also provide a technology base from which U.S. industry can demonstrate its leadership role in the world market. The completion of the Mod II will effect a demonstration of the final transfer of Stirling technology to the United States.

Thank you, Mr. Chairman, for this opportunity to appear before this important subcommittee. I would be pleased to answer any questions at this time.

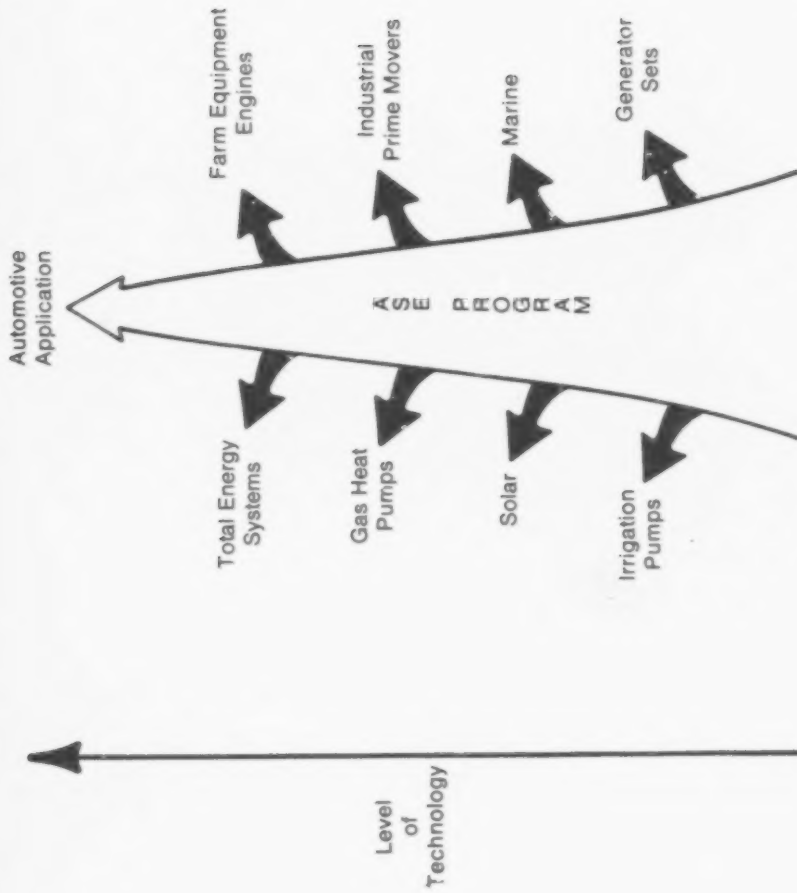


Fig. 1 Spin-Off Applications from Automotive Stirling Technology

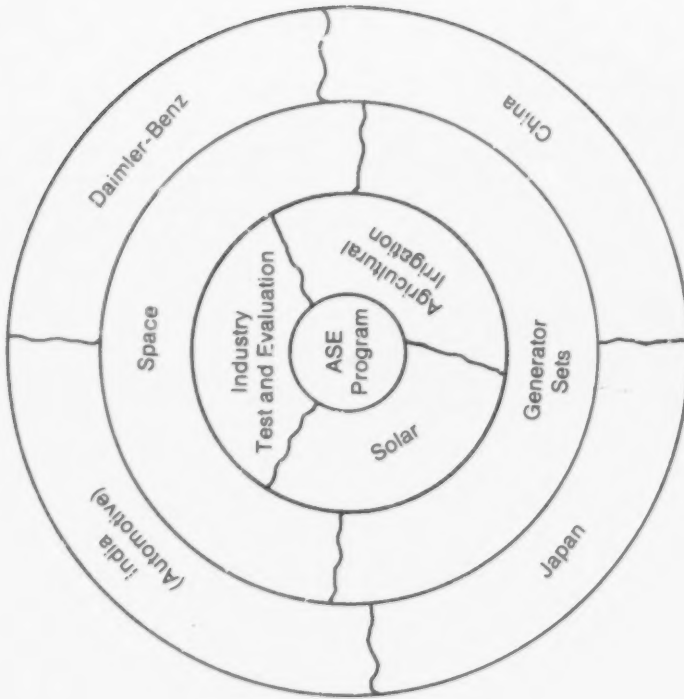
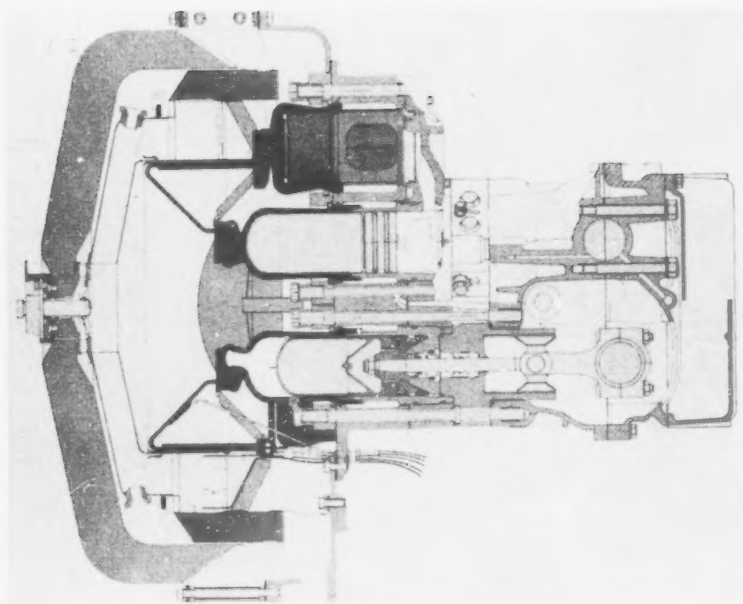
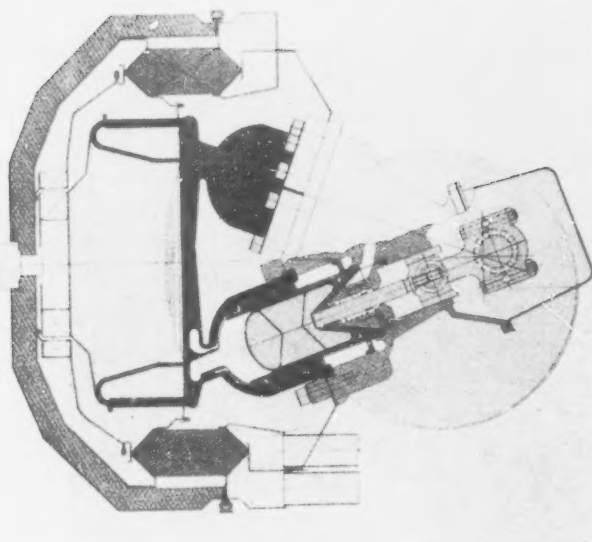


Fig. 2 Activities of Interest Surrounding the ASE Program



Mod I



Mod II

Fig. 3 Comparison of Mod I and Mod II Engine Cross Sections

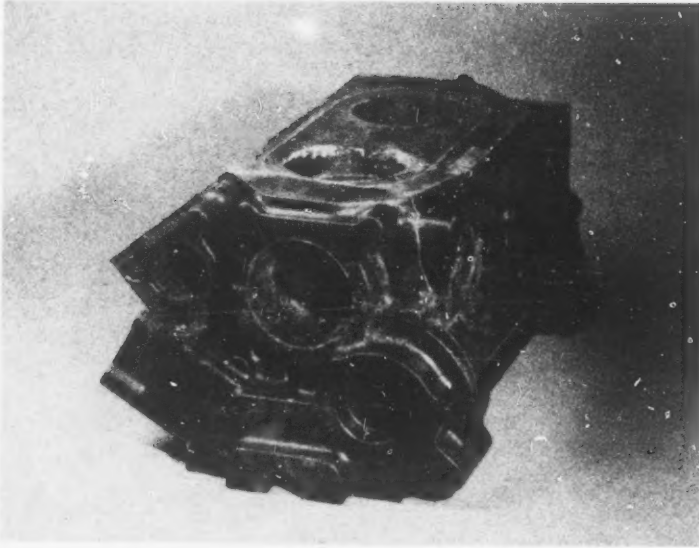


Fig. 4 Wax Model of V-Block

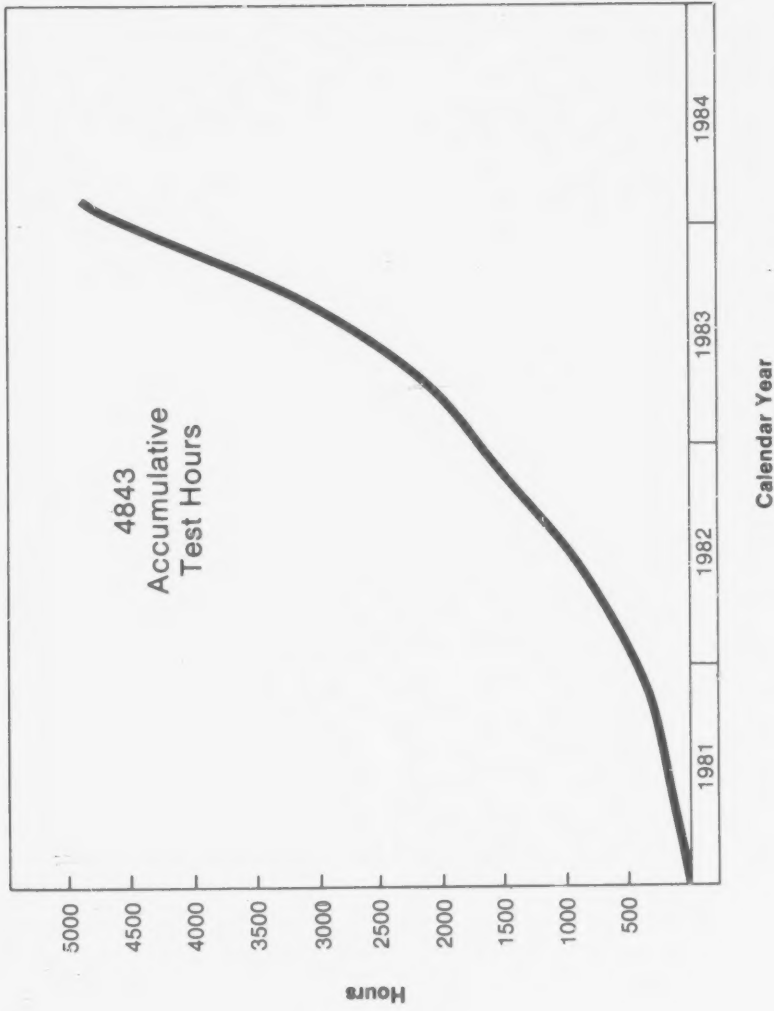
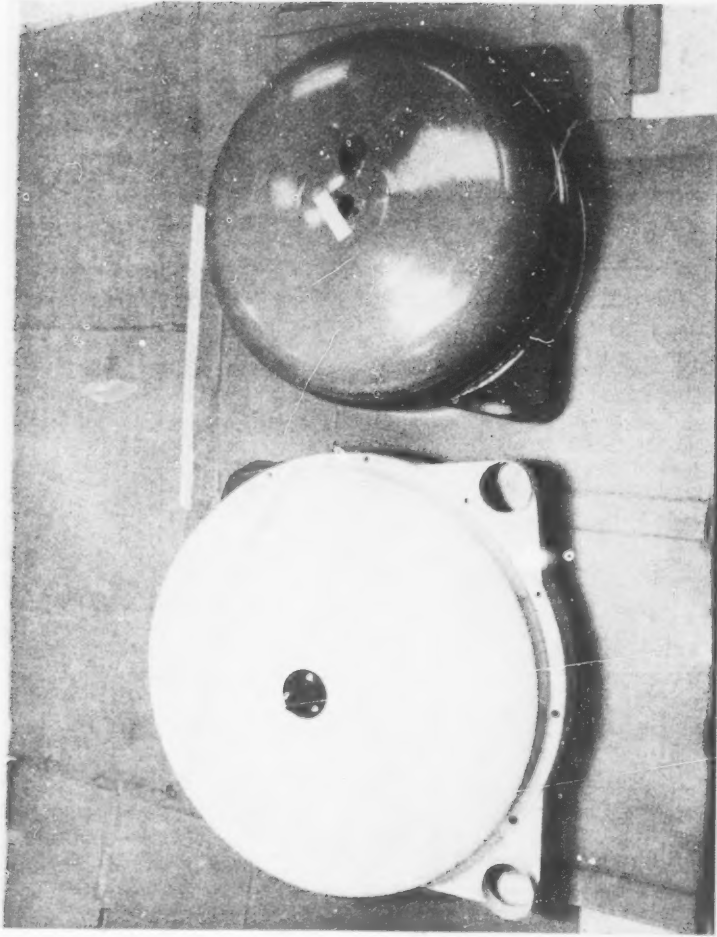


Fig. 5 Mod I Engine Test Hours



Mod I

Upgraded Mod I

Fig. 6 Comparison of Outer Burner Covers of Mod I and Upgraded Mod I Engines

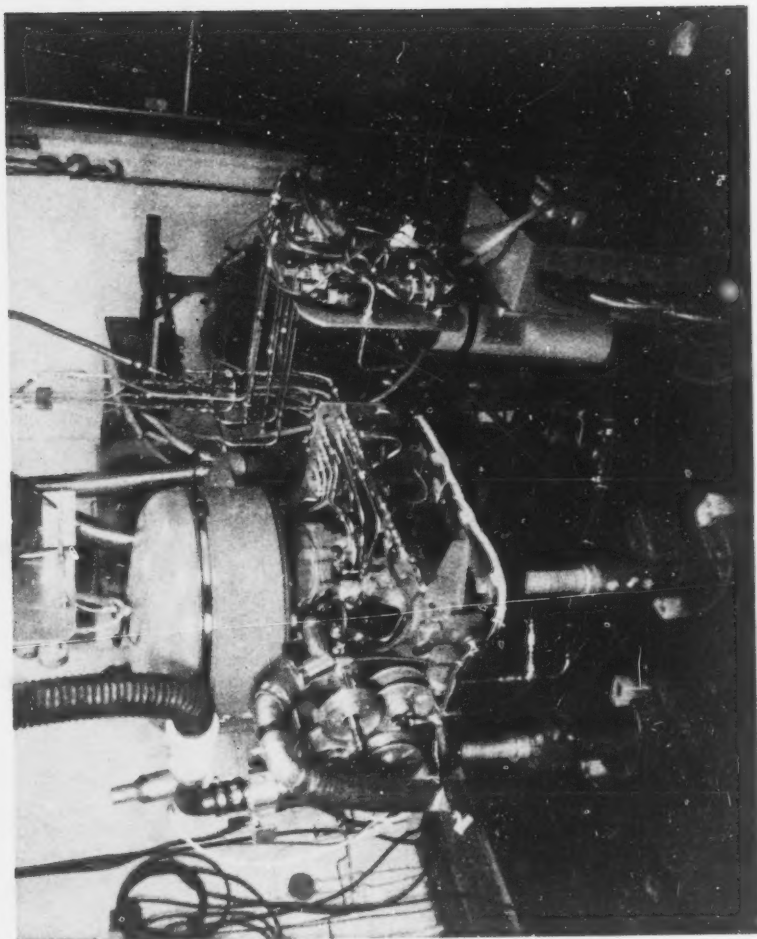


Fig. 7 Upgraded Mod I Installed in a Test Cell

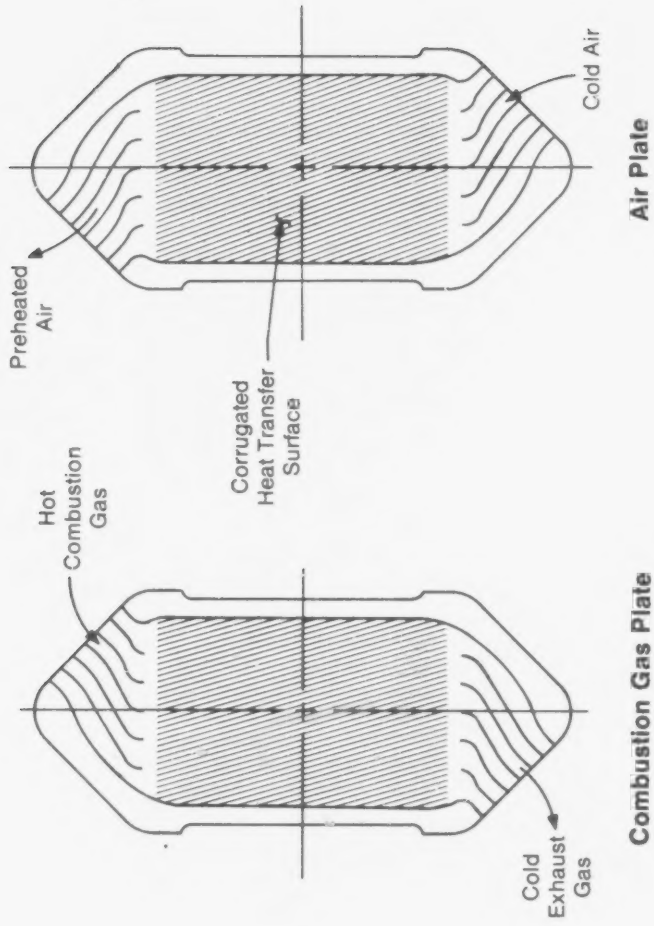


Fig. 8 Mod II Ceramic Preheater

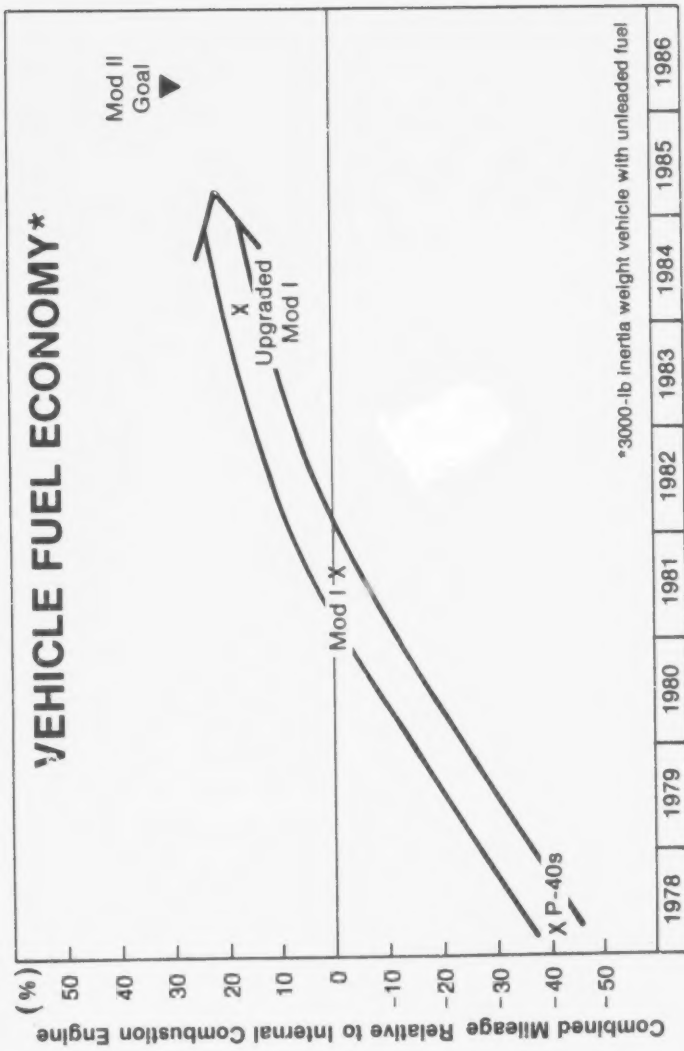


Fig. 9 Progress Made Toward an Increase in Fuel Economy

Degree of Stirling Engine Technology Transferred

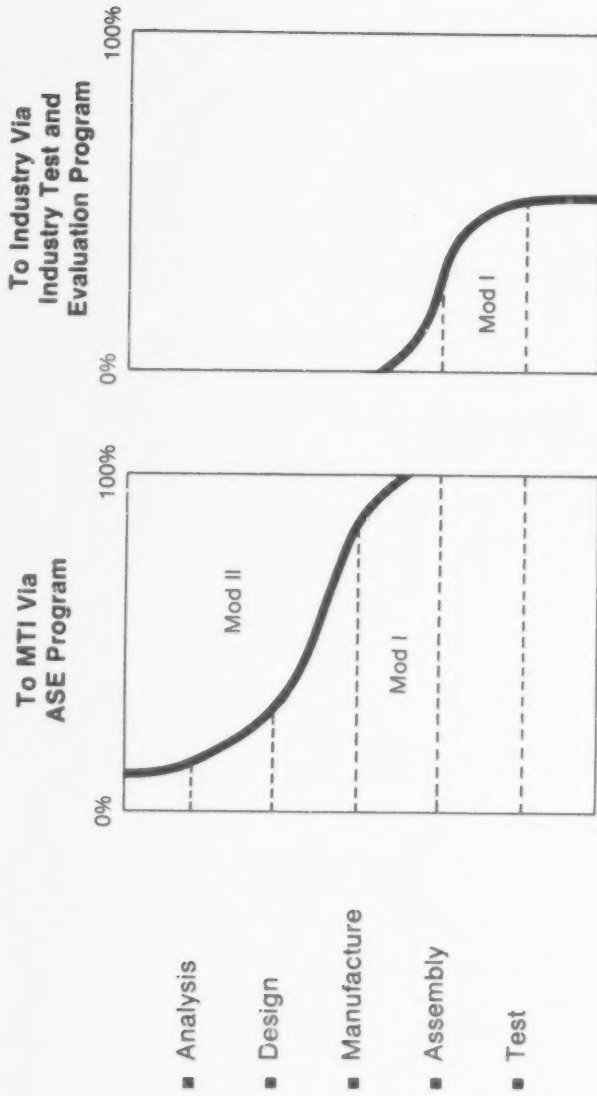


Fig. 10 Status of Stirling Technology Transfer

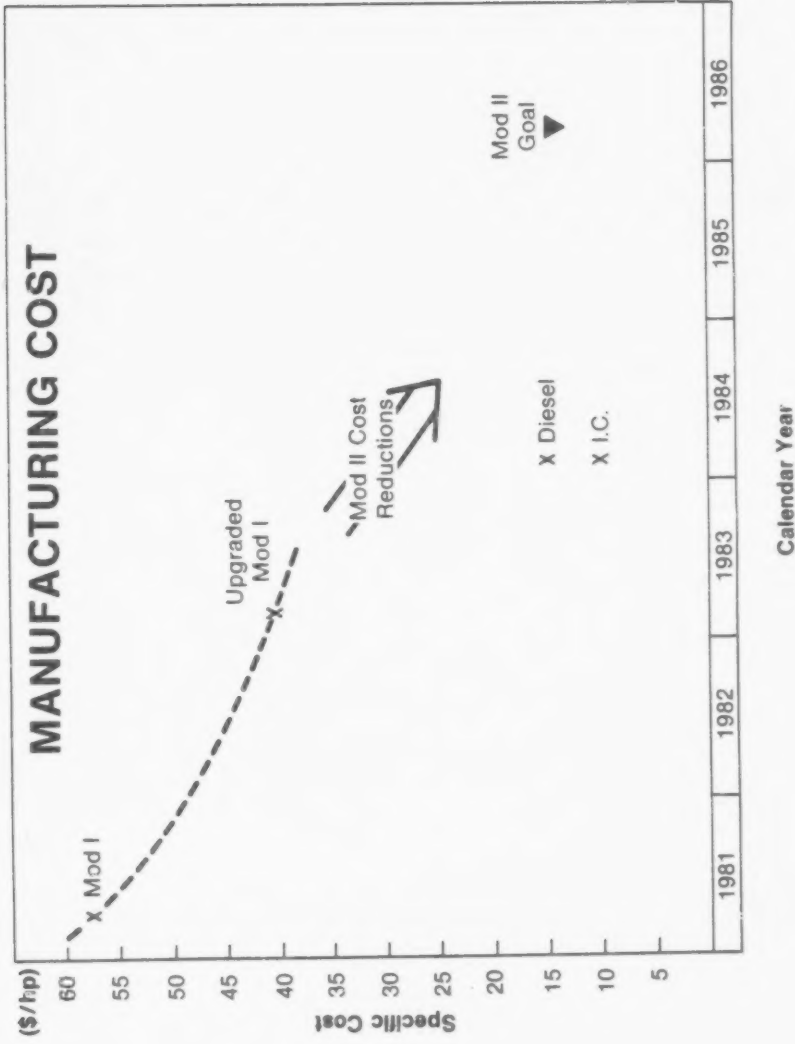


Fig. 11 Projected Cost Reductions for Mod II Engine

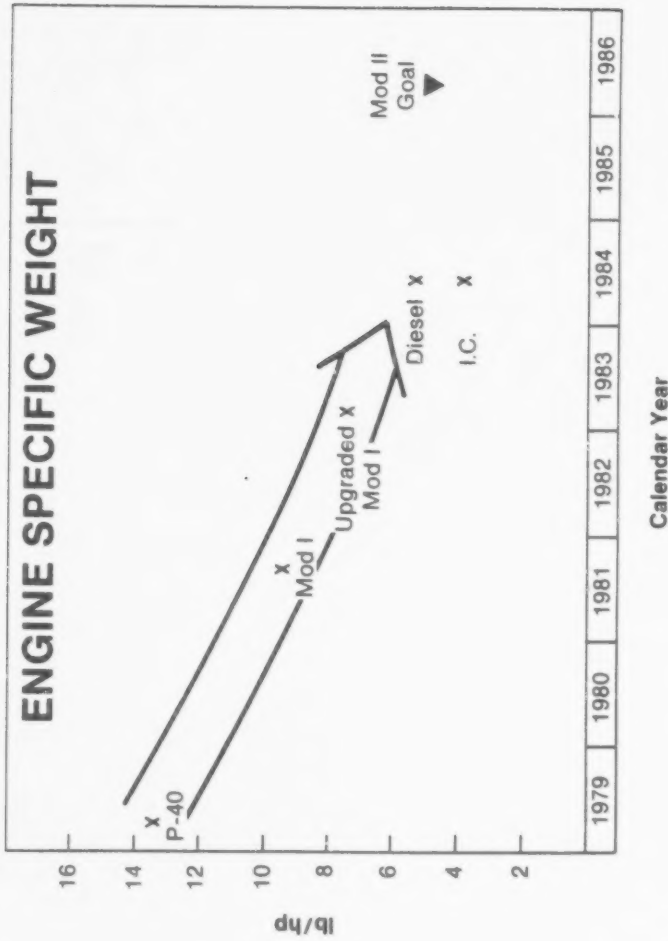


Fig. 12 Projected Reduction in Specific Weight of Mod II Engine

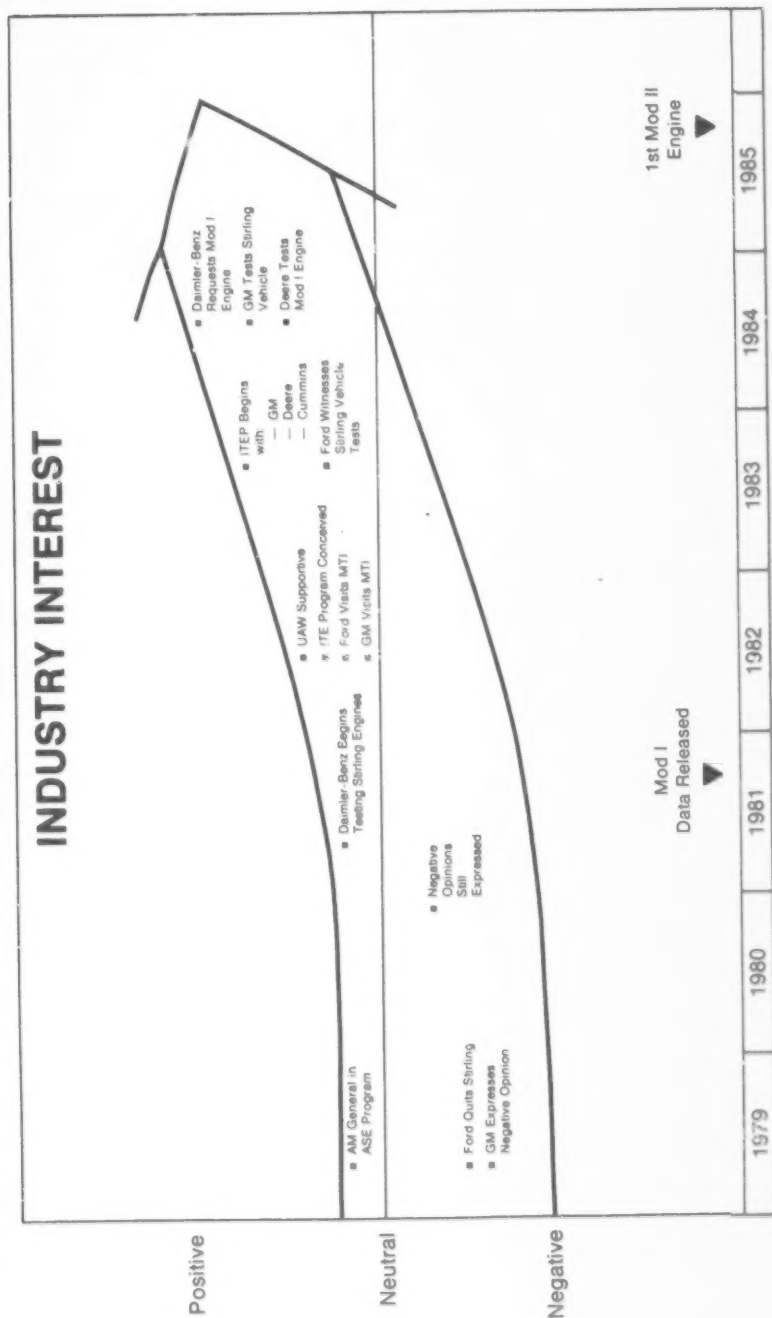


Fig. 13 Demonstrated Industry Interest in Stirling Engine Development

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Mr. GLICKMAN. The next witness is Dr. James Mueller, with the University of Washington, professor of ceramic engineering.

Dr. MUELLER. I will take a few moments to get the slides ready.

Mr. GLICKMAN. OK. Sure.

I hate to do this to you, but I have to leave here. I would like to leave here in 45 minutes. And so any way that you could accelerate your testimony—like I said, it will all be included in the record—it would be most useful to me.

STATEMENT OF JAMES I. MUELLER, PROFESSOR, CERAMIC ENGINEERING, DEPARTMENT OF MATERIALS SCIENCE AND ENGINEERING, UNIVERSITY OF WASHINGTON, SEATTLE, WASH.

Dr. MUELLER. In order to speed up the proceedings, if you don't mind, I shall read my testimony.

Mr. GLICKMAN. That's fine.

Dr. MUELLER. Mr. Chairman, members of the committee, over the past 18 months, a series of meetings have been held, attended by 21 individuals from 12 U.S. companies involved in the application of ceramic materials to heat engines. The purpose of these discussions was to summarize concerns and recommendations regarding the need and implementation of a major development initiative for such a program and to so inform the appropriate branches and agencies of the Government.

On behalf of these individuals, I wish to express appreciation for the opportunity to share these views with you today.

I believe an introduction review may be helpful in gaining an insight into the importance of an appropriate research and development program in this area. In so doing, certain excerpts will be taken from an overview paper I presented at a National Science Foundation meeting last June.

Much of the advanced technology affecting the U.S. economy and national defense is materials-limited. New systems and/or substantial improvements in the capabilities and efficiencies of existing systems could be achieved if new or improved materials were available.

This is particularly true of the potential utilization for advanced ceramic materials in transportation and energy applications, such as the uncooled diesel and gas turbine engines, production of synthetic fuels, cogeneration, waste heat recovery, and solar concentrator electrical generation.

The substitution of ceramic materials for metals in heat engines has been given substantial worldwide attention in recent years. It should be noted that the prime purpose for considering these replacements in the early 1970's was to utilize the higher-temperature capabilities of ceramics to improve automotive and truck emissions.

With the development of the oil crisis in the midseventies, the potential for fuel economy was also recognized, and it is now apparent that ceramics can also replace vulnerable metals in this application. In this country, the first major Federal-funded program was the Ford-Westinghouse study initiated by DARPA in 1971.

This involved the expenditure of approximately a \$115 million not including corporate funding, during fiscal year period 1974 to 1981, and resulted in significant progress.

The early success of this program, and the developing fuel crisis, led to additional support. In their final report on the DARPA program, Ford stated, and I quote, "With respect to the question, 'Can ceramics work,' the DARPA/Ford program has shown that, 'Yes, it can be done.' The real question on which we must now focus is: 'Can it be done consistently and reliably so it won't fail?' In ceramics, because of their extremely probabilistic behavior, the 'it won't fail' phase really has to be accomplished through a research effort. The dilemma is, however, that production development-type funding is not normally applied to address a research issue. As a result, a step-by-step approach should probably be taken."

This last statement definitely addresses where we are today. The feasibility of concept has been proven, but the research necessary to improve beginning materials and their processing leaves considerable to be accomplished.

The British were the first to become involved in ceramics for heat engines, followed by a substantially larger effort in this country. West Germany entered the picture in 1974, with Japan following in 1977. One of the prime differences between our programs and those across each of our bordering oceans is that both the Japanese and the West Germans have placed a larger percentage of Government moneys in support of materials suppliers and processors. This has caused some observers to feel that the United States is no longer in the dominant position worldwide.

Only a small fraction of U.S. research support for heat engine development has been allocated to ceramic materials suppliers. This and the lack of funding to improve processing or manufacturing of ceramic components could be the principal reason why the U.S. position is weakening in this area. If we are to be competitive, this segment of our industry needs immediate attention.

We are at a point of decision, one which will require a major cooperative effort between Government and industry, since it will improve substantial outlays of money by both if U.S. industry is to be competitive in this market area.

Johnson, of the Argonne Research Laboratory, recently published an economic analysis of the structural ceramics research program, in which they predicted the U.S. potential penetration for ceramic components in heat engines. The use of ceramics as a structural material in high-technology applications involves reliability factors never previously considered for this type of material, and is also dependent upon relatively new materials. Since such an effort effectively "started from scratch," the research to understand the materials properties and the development of processing methods necessary to produce a suitable engineering product requires funding beyond the abilities of any single company or even a consortium. Although there are numerous defense applications of these materials, their future will be in the civilian sector.

Obviously, the high potential exists, but what about the high risk? During the past several years, representatives from U.S. engine manufacturers and producers of ceramic materials discussed various aspects of this program.

Mr. GLICKMAN. Excuse me, Dr. Mueller. Why don't we do this, because of our time bind: Since your entire statement will appear in the record, I have some questions I want to ask you.

Dr. MUELLER. Fine.

Mr. GLICKMAN. Maybe what we could do is just assume that you've read your complete statement, and let's get to the questions.

Dr. MUELLER. May I go to a supplemental portion of it, Mr. Chairman?

Mr. GLICKMAN. Sure. Go ahead.

Dr. MUELLER. Let's see, we need to go—what I would like to do here is to point out to the committee, which is in my supplemental material which was just furnished to your committee this morning. And I may here—

Mr. GLICKMAN. The committee will take note specifically of your conclusions on pages 11 and 12, which have some recommendations in terms of the national research program in ceramics, the effect of foreign competition. I don't want to give short shrift to your suggestions—

Dr. MUELLER. Thank you.

Mr. GLICKMAN [continuing]. Because I think there is some work that we can do here in encouraging that.

Dr. MUELLER. To that, Mr. Chairman, I would like to add that this group of people from industry was assembled upon a suggestion of several staffers from both sides of Congress, asking what did industry feel about this total program, that most of the response they had had in most of these various committees had been from—mainly—from the agency side.

Mr. GLICKMAN. Yes.

Dr. MUELLER. And so that was the purpose of putting this group together, and those were the conclusions that were derived.

Subsequent to the preparation of my printed copy, it was suggested that I make a few comments comparing the U.S. program to that of the Japanese.

We are the leaders in design and testing of engines utilizing advanced ceramic materials. But they have a substantial lead in materials processing and fabrication. In fact, several of our engine companies are using Japanese-made components because of their availability and superiority.

May I now take a few comments to mention why. First, both of them—both their Government and their industry have developed long-range plans based upon previously established objectives; for instance, most major Japanese companies have publicly stated their goals for the early 21st century and have geared their research to meet those goals.

The Japanese Government established R&D themes or projects of 3-to-10-year durations, then sustained them with funds allocated in 1-to-4-year increments. Second, agencies have established strong interagency liaison and with industry and have encouraged the formation of strong associations whose directors are usually officers of affiliated corporations.

These associations are actively involved in government planning for future programs.

Third, while the United States has spent millions of dollars in proving the concept, the Japanese have spent billions of yen on

processing and fabrication technology, which incidentally they developed and did not copy. They also have many more ceramic companies involved than we do.

Let us compare organization participation on advanced or fine ceramic research and development—will bring the topic into focus. I will comment on the Japanese organizations, as you are probably familiar with the U.S. agencies.

The Ministry of International Trade and Industry, or MITI, is one of the prime movers in their Government, and these offices have direct responsibility for fine ceramics development. Five GIRI laboratories are involved in the fine ceramics area. The Science and Technology Agency supports relevant work in three major laboratories. Two of these national laboratories are interested in design width and the use of advanced ceramics, and two are involved in beginning powder development.

I have purposely omitted both university and research foundations or institutes which receive support in these programs.

As far as outside or industrial organizations are concerned, the difference is obvious. Hopefully, the group which developed the position paper described this morning will become a nucleus of an organization similar to that one in Japan.

In closing, may I again express my appreciation for the opportunity to bring to this committee our views on a significant problem facing a portion of our Nation's industry.

Mr. GLICKMAN. So it would be a fair statement, Dr. Mueller, that the Japanese effort in ceramics is much greater, much deeper than ours?

Dr. MUELLER. Very, very true.

Mr. GLICKMAN. If we established a national research and development program in ceramics, as indicated in your statement, I wonder if you have any thoughts on who should manage the program. Should it be under one of the laboratories that we currently have? Are our current mechanisms in government sufficient to meet and work with industry in setting the goals and priorities in this area?

Dr. MUELLER. Well, far be it from me, Mr. Chairman, to suggest which agency might be the prime one to manage such a program. Possibly, a committee—and I might add that a suggestion in your bill, title II of a number who escapes me at the present time, which you furnished, does offer a possibility for coordination of this type.

Mr. GLICKMAN. You mean in the Materials bill—

Dr. MUELLER. Yes.

Mr. GLICKMAN. The Generic bill?

Dr. MUELLER. Yes, the Generic bill. Right.

Mr. GLICKMAN. What I am saying is, let's say that, you know, we have four labs under the Department of Energy. We have some variety of Department of Defense-related activities.

Dr. MUELLER. Yes.

Mr. GLICKMAN. NASA has some work, but that in ceramics is being done in conjunction with the Department of Energy.

My question is, "Should we just take one of our existing or all of our existing labs within the Department of Energy, since they seem to be the bulk, the heart, of the materials work, and just give it to them to do?" Or do you have any thoughts on that line?

Dr. MUELLER. Well, let me say this, that I think that the Oak Ridge program on ceramic technology and the NASA-Lewis program on ceramic technology do have some coordinated efforts. Those two are the principal labs involved in the heat engine material development at the present time.

Mr. GLICKMAN. That's where at least right now, if you were to place this program, it would be?

Dr. MUELLER. Yes, sir.

Mr. GLICKMAN. In Oak Ridge and NASA-Lewis?

Dr. MUELLER. Yes, sir.

Mr. GLICKMAN. OK. Well, we'll talk a little more about how to do this. But I do think you made a good suggestion; it's that I think maybe the department needs to be pushed into moving ahead specifically with this kind of program. They may be doing some generic in this area. And we maybe can push that along legislatively.

I want to ask you a question in reference to something that I think may have been raised to you before. There are new Department of Defense guidelines on the export of composite materials and technology, and they are raising important questions in the industrial and academic communities. These are not just with composites.

Dr. MUELLER. Yes, sir.

Mr. GLICKMAN. They're about everything. The Department of Defense—and this is my feeling—wants to push its tentacles into controlling almost all exports and deciding what we can export and what we can't.

But simply stated, the guidelines place restrictions on revealing results of materials research. Those restrictions are thought unduly prohibitive, I think, by many in the private sector to the free exchange of information and results to maintain U.S. competitiveness.

I wonder if you are familiar with those guidelines, if you would comment on them.

Dr. MUELLER. I am familiar with the guidelines, Mr. Chairman. I was able to review the draft of those guidelines a little over a year ago. We had a presentation last month by Frank Capper of the Department of Defense, whose office is in charge of this area, giving us what is probably the final draft.

It appears that, for the most part, the transfer of information on truly basic research is not on a restricted basis. What they're doing is restricting information on processing and methodology and testing and end-use application.

Now, if the basic research in any way should identify end-use application, then that would be restricted. And I guess that's where one of the very, very gray areas comes in, because much of our basic research does have end-use application.

Mr. GLICKMAN. Well, in your view, who would benefit most by restricting information flow in these areas being proposed? The United States, or Japan, or Europe?

Dr. MUELLER. Obviously, I—I don't think there's—my own personal opinion, Mr. Chairman, is there's no beneficiary. We have—there has been a lot of concern expressed publicly and privately about how the information transfer on this heat engine situation is one way, that everything is going out of the United States to Japan

and to West Germany and to Sweden and to France and Italy and others who are interested.

I've made two trips to Japan, and I do not find a one-way flow of information at all. I find that if a person is open and talks to them in a professional manner, that you get as much information from a Japanese company or a Japanese laboratory as you can get from a U.S. company.

Mr. GLICKMAN. Well, what I wanted to know is, are these guidelines designed with respect to the Japanese or the Soviet Union?

Dr. MUELLER. I think they're designed with respect to the Soviet Union.

Mr. GLICKMAN. So the idea—the idea is to try to restrict items, technologies that have military applications, I assume.

Dr. MUELLER. I understand. But that also includes items which have many other applications—

Mr. GLICKMAN. Yes.

Dr. MUELLER. Mr. Chairman.

Mr. GLICKMAN. Also, the question is defining applied versus basic. I assume that's a very amorphous—

Dr. MUELLER. It depends upon where you sit.

Mr. GLICKMAN. And how—and where your goals are.

Dr. MUELLER. Exactly.

Mr. GLICKMAN. One can put an applied project into a basic project and vice versa, if one is creative.

Dr. MUELLER. Exactly.

Mr. GLICKMAN. OK. Thank you.

Mr. Boehlert.

Mr. BOEHLERT. No questions.

Mr. GLICKMAN. The brevity of our dealing with you today in no way diminishes the importance of your testimony.

Dr. MUELLER. Thank you.

Mr. GLICKMAN. I want to just tell you that you have specific items in your testimony which I think we are going to try to include in either committee report language or in actual statutory language itself in the materials area. So we are appreciative of your being here.

Dr. MUELLER. Thank you very much.

[The prepared statement of Dr. Mueller follows:]

TESTIMONY TO THE SUBCOMMITTEE ON
TRANSPORTATION, AVIATION AND MATERIALS
U.S. HOUSE OF REPRESENTATIVES

February 22, 1984

by

James I. Mueller
Professor of Ceramic Engineering
University of Washington
Seattle, Washington

Over the past eighteen months, a series of meetings have been held, attended by 21 individuals from 12 U.S. companies involved in the application of ceramic materials in heat engines. The purpose of these discussions was to summarize their concerns and recommendations regarding the need and implementation of a major development initiative for such a program and to so inform the appropriate branches and agencies of government. On behalf of these individuals, I wish to express appreciation for the opportunity to share these views with your committee.

I believe an introductory review will be helpful as a means of gaining an insight into the importance of an appropriate research and development program in this area. In so doing, certain excerpts will be taken from an overview paper I presented at a National Science Foundation Workshop last June.

Much of the advanced technology affecting the U.S. economy and national defense is materials limited. New systems and/or substantial improvements in the capabilities and efficiency of existing systems could be achieved if new or improved materials were available. This is particularly true of the

potential utilization for advanced ceramic materials in transportation and energy applications, such as uncooled diesel and gas turbine engines, production of synthetic fuels, cogeneration, waste-heat recovery and solar concentrator electrical generation. The substitution of ceramic materials for metals in heat-engines has been given substantial world-wide attention in recent years. It should be noted that the prime purpose for considering these replacements in the early 1970's was to utilize the higher temperature capability of ceramics to improve automotive and truck emissions. With the development of the oil crisis in the mid-70's, the potential for fuel economy was also recognized and it is now apparent that ceramics can also replace vulnerable metals in this particular application.

By their very nature, ceramic materials are brittle. This does not mean they are weak but rather they have little forgiveness, or strain capability. They therefore fail catastrophically rather than with the relatively slow deformation exhibited by most metals. Due to this and lower tensile strength, they are susceptible to the presence of flaws which in the present state of our processing technology occur all too often. The designer therefore questions the reliability of ceramic materials and we are low on the learning curve in the solutions to this problem.

In this country, the first major federal-funded program was the Ford-Westinghouse study initiated by DARPA in 1971. Although the principal thrust of this project was to improve methodologies for designing with brittle materials, the ceramic gas turbine engine was used as a model. The early success of this program and the developing fuel crisis led to additional support, as shown in Figure 1 after Lenoe (1). This involved the expenditure of approximately \$115 million, not including corporate fundings, during the

fiscal year period 1974-81 and resulted in significant progress. In their final report on the DARPA program, Ford reported (2):

"With respect to the question: 'Can ceramics work?' The DARPA/Ford program has shown that 'Yes, it can be done.' The real question on which we must now focus is: 'Can it be done consistently and reliably so that it won't fail.' . . . In ceramics, because of their extremely probabilistic behavior, the 'it won't fail' phase really has to be accomplished through a research effort. The dilemma is, however, that production development-type funding is not normally applied to address a research issue. As a result, a step-by-step approach should probably be taken." This last statement definitely addresses where we are today. The feasibility of the concept has been proven but the research necessary to improve beginning materials and their processing leaves considerable to be accomplished.

The British were the first to become involved in ceramics for heat engines, followed by a substantially larger effort in this country. West Germany entered the picture in 1974 with Japan following in 1977. One of the prime differences between our programs and those across each of our bordering oceans is that both the Japanese and West Germans have placed a larger percentage of government monies in support of the materials suppliers and processors (3). This has caused some observers to feel that the U.S. is no longer in the dominant position world-wide (4). (Figure 2).

Only a small fraction of U.S. research support for heat engine development has been allocated to the ceramic materials suppliers. This and the lack of funding to improve processing (manufacturing) of ceramic components could be the principle reason why the U.S. position is weakening in this area. If we are to be competitive, this segment of our industry needs immediate attention.

We are at a point of decision, one which will require a major cooperative effort between government and industry since it will involve substantial outlays of money by both if U.S. industry is to be competitive in this market area. Johnson et al. recently published an economic analysis of the structural ceramics research program in which they predicted the potential U.S. penetration for ceramic components in heat engines, as shown in Table I (4). The use of ceramics as a structural material in high technology application involves reliability factors never previously considered for this type of material and is also dependent upon relatively new materials. Since such an effort effectively "started from scratch," the research to understand the materials properties and the development or processing methods necessary to produce a suitable engineering product requires funding beyond the abilities of any single company or even a consortium. There are numerous defense applications of these materials but their future will be in the civilian sector.

Obviously, the high potential exists, but what about the high risk? During the past several years, several meetings took place during which representatives from U.S. engine manufacturers and producers of ceramic materials discussed various aspects of this problem. All agreed that the cost of materials and process development would be prohibitive without long term government assistance. If we now review the National Materials & Mineral Progress Plan and Report to Congress, we note President Reagan stated: "Any government-financed research and development action activities will concentrate on long-term, high risk, high potential payoff projects with the best chance for wide generic applications to materials problems and increased productivity." Certainly this application of ceramics in heat engines meets these qualifications.

During these meetings, it was noted that while foreign companies are investing heavily in advanced ceramic structural materials, their governments permit tax write-offs and depreciation not permitted in this country making it difficult for U.S. industry to compete. This relates to another of the President's materials policy statements, that . . . "favorable tax incentives in the Economic Recovery and Tax Act (should) stimulate private research and development to ensure the availability of materials essential to the nation's economy and national defense." The question here, and one which I cannot answer is--do today's tax incentives offer sufficient stimulation to already depressed industries?

Another factor that must be considered by those whose funding is being utilized in the development of high technology ceramics is time--the bridge from concept to commercialization. Today few would look upon the automotive spark plug as being high technology. Yet 40 years ago ceramists world-wide, particularly in Germany, were in the midst of basic research involving the sintering of aluminum oxide. In the immediate post-WW II period, the U.S. automotive industry, recognizing the need for a spark plug with higher temperature capabilities with high voltage insulation properties, turned to sintered aluminum oxide as the appropriate solution. It took almost 25 years to get from research to commercial production (5). Based upon this time frame and using 1971 as a starting point, the earliest utilization of ceramics in a gas turbine could be in the mid 1990's, a period which matches the estimates of engine manufacturers in West Germany, Japan, and Sweden.

If we are indeed in the research phase in the development of ceramics for heat engine applications, can we compare our present systems with another, more mature area involving high technology ceramics? The

utilization of ceramics in the electronics industry may be an appropriate example. Professor Bowen of MIT generously offered information on the 1981 value in U.S. sales of certain ceramic components to the electronics industry which are given in Table II (6).

The solutions to today's problems for heat engine ceramics are substantially greater than those which the electronics ceramic industry faced 15 years ago. It is safe to assume that the U.S. holds about at least a 40% share of the world's market for electronic ceramics which according to Bowen's figures, is about \$1.3 billion. If the U.S. were to obtain 40% of the world's market for ceramic engine components, an extrapolation of Johnson's estimate would be \$6.1 billion per year by the year 2000.

CONCERNS

The considerable discussion involved concerns about U.S. materials R & D policy and about preliminary plans for a heat engine ceramics program initiative as presented by the National Aeronautics and Space Administration's Lewis Research Center and the Department of Energy's Oak Ridge National Laboratory. The following statements summarize these concerns:

- ° The availability of reproducible, quality starting powders for fabrication of advanced structural ceramics is inadequate.
- ° Current ceramic materials are highly variable and result in inadequate reliability, resulting in an excessive risk for current engine development programs.
- ° A high priority effort of iterative processing and equipment development is required to achieve mature process control, improved materials properties and net-shape fabrication capability.

- ° Foreign competition in this area threatens the viability of U.S. industry.
- ° The stated U.S. National Materials Policy should include the capability to focus on critical materials cases. Although substantial government funding has already been dedicated to materials R & D, there has not been appropriate recognition by its agencies on proper focus or objectives. Specifically, in the case of the heat engine program, the planning resulted in efforts guided into commercialization programs rather than allocating resources towards a ceramic technology program. Only by the establishment of appropriate goals with their attendant objectives, implemented by a sustaining research and development effort, can our country focus on a national development effort.
- ° It is imperative for government laboratories to support industrial R & D programs through cooperative efforts to identify and achieve program objectives. If technology is to produce new jobs and improve our economy, it must be based in industry, with coordinated efforts involving government laboratories and universities, utilizing the special expertise of all concerned.
- ° Government contracting methods need thorough reassessment relative to tax incentives and proprietary information practices as these are crucial to maintaining a competitive U.S. posture in the international marketplace. It is sorely apparent that other countries are making an overwhelming effort to bring advanced technology products into the world's market without the penalties currently imposed upon U.S. industry by unfavorable tax regulations

and the requirements of unreasonable revelation of key innovative competitive factors relative to product development and production.

TECHNOLOGY BENEFITS AND PROGRAM REQUIREMENTS

The first question considered by the group was whether or not potential benefits of the use of advanced ceramics materials in heat engine technology would justify a major R & D effort. The following is a list of advantages or benefits:

- | | |
|--------------------------------------|---|
| . Greater fuel economy | . Applicable to both commercial and military requirements |
| . Utilization of low quality fuels | . Deletion of cooling systems |
| . Compatibility with synthetic fuels | . Resistance to corrosion and erosion |
| . Reduction in strategic materials | . Improved emissions control |
| . Potential cost reduction | . Wider range of properties |
| . Reduced maintenance | . Would lead to new industries |
| | . Would increase the U.S. GNP |

It was the consensus that a major program was required if the U.S. is going to meet international competition.

The goals and organization of such a proposed program were considered and, as stated, most agreed that the major constraints were high risk, high cost and the lack of reliability in present materials since primary funding in the past was directed towards the proof of concept programs with engine manufacturers which have demonstrated feasibility.

A proposed solution was to substantially increase the level of effort for ceramic materials producers and fabricators. The following were topics where significant improvements should be sought by a future program. These are in total agreement with the recommendations of the National Materials Advisory Board Committee on Reliability of Ceramics for Heat Engines (7).

- . Beginning Powders
- . Strength
- . Reliability
- . Cost Effectiveness
- . Processing Methods
- . Nondestructive Evaluation
- . Finishing

It was the majority belief that powder development and component processing, including finishing, were the keys to the required reliability and that advanced NDE techniques are necessary. This is compatible with the objectives identified by NASA/LRC and DOE/ORNL for their ceramic initiatives. It was further agreed that the ceramic materials producers and fabricators should be encouraged to participate as possible recipients of new funding, but that judgments for selection be based upon choosing the company(s) best qualified in terms of expertise, facilities and ideas to undertake the jobs. There must be close liaison with continuing heat engine programs as the achievement of reliability will require iteration between material development and engine testing of components.

The most effective utilization of government and university laboratories also received considerable attention. All recognized the existing expertise and agreed that its use would be paramount to the success of the program. Numerous topics were suggested as being suited for study by those groups, including

- . generic basic research on materials
- . characterization methods
- . development of NDE
- . corrosion and erosion research
- . advanced processing methods

The consensus opinion was that both be supported on primarily basic research but that certain government and university laboratories be recognized as

having unique expertise in specific areas and that these be encouraged to further develop those capabilities. This, for example, would result in laboratories with unique facilities for testing and evaluation, characterization, finishing and NDE. These would be available to industry on a contract basis, reducing the need of capital expenditures for redundant capabilities. It was further stated that encouragement should be given universities to initiate and accomplish appropriate basic research which could result in improved structural ceramics and a more complete future understanding of their inherent and potential properties. Although research on advanced processing was deemed appropriate for university efforts, several suggested that improvements in current processing techniques would be more efficiently studied within industry.

To assure success of such a program, organizational improvements should be made in order that all activities are implemented in a coordinated and effective manner while maintaining the individuality of each activity. This coordination should assure that the research, development and application sectors maintain mutually effective and cooperative relations in order that use of the results will be maximized. It was felt, therefore, that the responsibility for coordination of the programs should be assigned within a single government activity, acting with a strong industrial advisory group.

It was also noted that foreign companies are investing heavily in advanced ceramic structural materials, and their governments are permitting tax write-offs and depreciation not allowed in this country. This makes it difficult for U.S. industry to compete and relates to another of the President's materials policy statements, that . . . "favorable tax incentives in the Economic Recovery and Tax Act (should) stimulate private research and

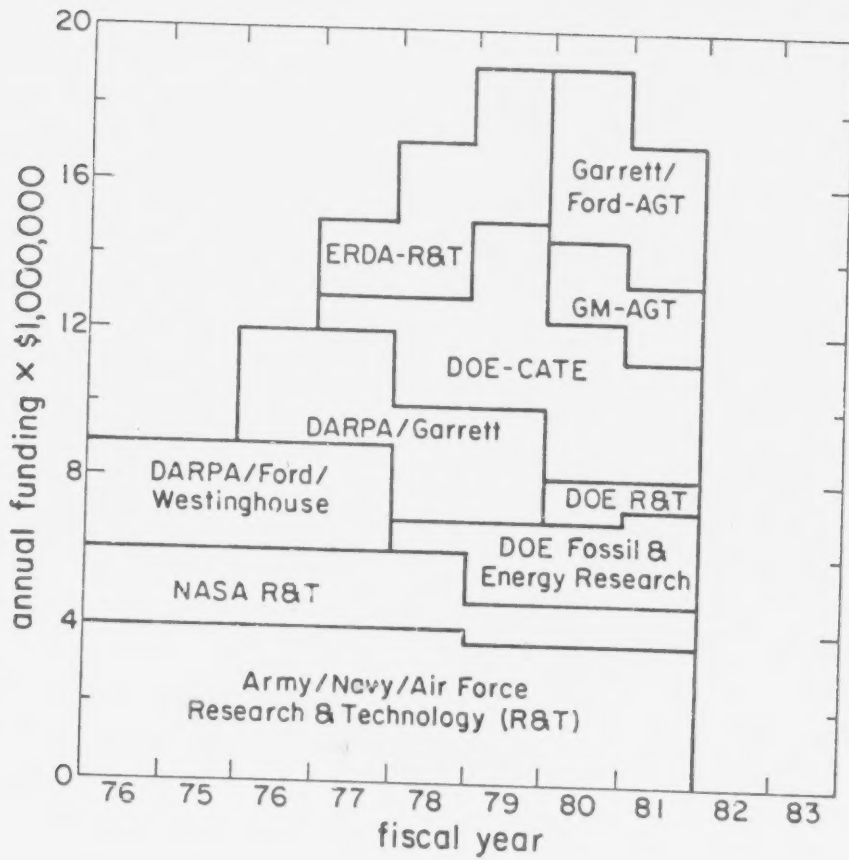
development to ensure the availability of materials essential to the nation's economy and national defense."

CONCLUSIONS

1. Cost, risk and reliability are the major constraints to the application of high technology ceramics to heat engines.
2. Foreign competition may be overtaking U.S. technology in this area due in a large extent to government-industry cooperation and commitments.
3. A national research and development program, with emphasis on research, should be established to improve domestic production of consistent, high quality ceramic powders and the concomitant processing with the ultimate goal being to develop structural ceramics technology for industrial and defense utilization.
4. The R & D required would be generic in nature, having applicability in high technology areas other than heat engines.
5. R & D programs should be funded to the ceramic industry and other industrial organizations with the capability and interest to contribute, and with continuing support to the heat engine programs as test-beds for the assessment of improved ceramic materials and components.
6. For such a program to be effective, it should be supported by sustained government funding supplemented by long-term corporate commitments.
7. University and government laboratories should be encouraged to develop and establish unique characterization capabilities which would be available to other laboratories and to industry for

environmental testing and data-base generation which can be used for design and design verification.

8. Initiation of this program at an increased level of funding is essential if U.S. industry is to remain competitive in the international marketplace.
9. A program should be immediately developed and implemented to offer encouragement of industrial participation through tax incentives and through the relaxation of existing bureaucratic requirements relative to multiple and short-term reporting and to the international revelation of innovative and competitive methods and products.
10. This national program must be coordinated, preferably by a single government office, with assistance from an industry advisory group to assure focused efforts, proper communication and coordination and continued, long-term planning.
11. This group will continue to meet periodically, with interim informal communication, with the intent to formalize its organization, to keep all informed of national and international developments and to advise our government relative to matters of interest and concern.



U.S. Funding of Ceramic Gas Turbine Engine Development
YRS 1974-1981

Figure 2

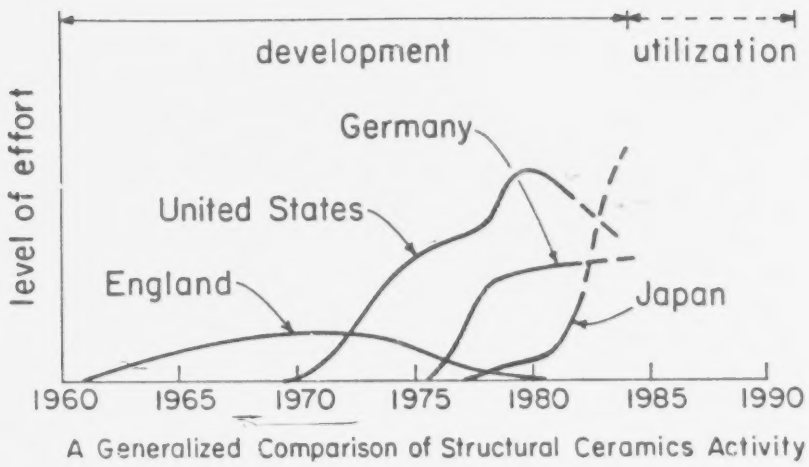


Figure 1

Table I
A Range of Market Penetration for Ceramic Components

	FOR YEAR 2000				
		% Market Penetration		Market Penetration	
	(1981\$ x 10 ⁶)	Low	High	Low (1981\$ x 10 ⁶)	High
<u>Diesel/gas turbine components</u>					
Piston, piston rings, valves ^a	\$ 1,807	0.05	0.20	\$ 90	\$ 361
Cylinder liners, head insert ^a	1,984	0.05	0.20	99	397
<u>Bearings</u>	6,379	0.05	0.30	319	1,913
<u>Turbochargers</u>	306	0.05	0.75	15	230
<u>Gas turbines, except aircraft</u>	449	0.05	0.30	22	135
Total	\$10,925			\$545	\$3,036

^aIncludes gasoline and diesel engine parts for all applications

Table II
U. S. Sales of Electronic Ceramics, 1981

Item	\$ Millions
Capacitors	400
Substrates/Packaging	500
Magnets	150
Magnetic Tapes	150
Thermistors	60
Varistors	30
TOTAL	\$1.290 billion

References

1. E. M. Leno: "Overview of DOD Ceramic Heat Engine Technology Projects," Proceedings of DOE/EMACC Meeting, CONF-820911, Department of Energy.
2. A. F. McLean and E. A. Fisher, "Brittle Materials Design, High Temperature Gas Turbines." Final Report. AMMRC TR 81-14, Ford Motor Co., March 1981.
3. J. I. Mueller: "Handicapping the World's Derby for Advanced Ceramics," American Ceramic Society Bulletin, Vol. 61, No. 5, 1982.
4. L. R. Johnson, A. P. S. Teotia and L. G. Hill, "A Structural Ceramics Research Program and Preliminary Economic Analysis," A Structural Ceramics Research Program: A Preliminary Economic Analysis," Argonne National Laboratory, Dec. 1982.
5. M. Berg, "The Sparkplug: A Case History," presented at the 6th Army Materials Technology Conference, Orcas Island, WA, July 1979.
6. H. K. Bowen, Personal communication.
7. "Reliability of Ceramics for Heat Engine Applications," Report Number NMAB-357, National Materials Advisory Board, National Academy of Sciences, Washington, D.C., 1980.

ATTENDEES AT (1982-1983)
CERAMIC COMPONENTS FOR ENGINE MEETINGS

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SUPPLEMENT TO TESTIMONY

BY

JAMES I. MUELLER

Subsequent to the preparation of my printed copy, it was suggested that I make a few comments comparing the U.S. program to that of the Japanese. We are the leaders in design and testing of engines utilizing advanced ceramic materials, but they have a substantial lead in materials processing and fabrication--in fact, several of our engine companies are using Japanese-made components because of their availability and superiority. May I take a few moments to comment on why?

TABLE III

R&D PROJECT OF HEAT PERFORMANCE

CERAMICS FOR FUTURE INDUSTRIES

(1981-1990)

"Deals with revolutionary basic technologies essential to the establishment of new industries which are expected to flourish in the 1990's."

First, both their Government and their industry have developed long range plans based upon previously established objectives. For instance, most major Japanese companies have publicly stated their goals for the early 21st century and have geared their research to meet those goals.

TABLE IV
JAPANESE PROGRAM FOR
HIGH PERFORMANCE CERAMICS

- 1 -- Research on beginning powders
 - Develop materials to achieve target values
- 2 -- Fabricate and test small model parts
- 3 -- Fabricate and test fullsize products
 - validation of process technologies
 - application techniques
 - evaluation of products

The Japanese Government establishes R&D themes, or projects of 3 to 10 year durations, then sustains them with funds allocated in 1 to 4 year increments.

TABLE V
JAPANESE ENGINEERING RESEARCH ASSOCIATION FOR
HIGH PERFORMANCE CERAMICS

- 15 PRIVATE COMPANIES
 - basic engineering development
 - production methods
 - application techniques
- 5 GOVERNMENT LABORATORIES
 - basic research - sintering, machining
 - fracture mechanics, evaluation

Second, Agencies have established strong interagency liason and with industry, have encouraged the formation of strong associations whose directors are usually officers of affiliated corporations. These associations are actively involved in Government planning for future programs.

TABLE VI
JAPAN FINE CERAMICS ASSOCIATION
MEMBER COMPANIES (4/30/83)

CERAMIC	41
CHEMICAL	33
ELECTRIC APPLIANCES	25
METALS	23
MACHINERY	23
AUTOMOTIVE	7
HEAVY EQUIPMENT	7
OTHER	17

TABLE VII
GROWTH RATE OF JAPANESE R&D

YEAR	TOTAL R&D	FINE CERAMICS
1981	100	100
1982	115	130
1983	123	155

Third, while the U.S. has spent million of dollars in proving the concept, the Japanese have spent billions of yen on processing and fabrication technology, which incidently they developed and did not copy. They also have many more ceramic companies involved than we do.

Let us compare organization participation on advanced, or fine ceramic research and development will bring the topic into focus. I will comment on the Japanese organizations as you are familiar with U.S. Agencies and laboratories.

TABLE VIII

JAPANESE ORGANIZATIONS RELATED TO FINE CERAMICS

GOVERNMENT

MINISTRY OF INTERNATIONAL TRADE & INDUSTRY

- Fine Ceramics Office, Consumer Goods Industry Bureau
- Office for Research & Development Project of Basic Technology for Future Industries, Agency of Industrial Science & Technology

GOVERNMENT INDUSTRIAL RESEARCH INSTITUTES

- Osaka
- Nagoya
- Kyushu
- Tohuko
- Chugoku

SCIENCE AND TECHNOLOGY AGENCY

- National Institute for Research in Inorganic Materials
- National Research Institute for Metals
- National Aerospace Laboratory

NATIONAL LABORATORIES

- Electrotechnical Laboratory
- Mechanical Engineering Laboratory
- National Chemical Laboratory for Industry
- Ship Research Institute, Ministry of Transport

PUBLIC ORGANIZATIONS

Engineering Research Association for
High Performance Ceramics

Japan Fine Ceramics Association

Engineering Research Association for
Advanced Gas Turbines

TABLE IX

U.S. ORGANIZATIONS RELATED TO
HIGH PERFORMANCE CERAMICS
GOVERNMENT

DEPARTMENT OF DEFENSE

- Air Force Materials Laboratory
- Army Materials & Mechanics Research Center
- Naval Research Laboratory

DEPARTMENT OF COMMERCE

- National Bureau of Standards

DEPARTMENT OF ENERGY

- Lawrence Livermore National Laboratory
- Los Alamos National Laboratory
- Oak Ridge National Laboratory
- Sandia National Laboratory

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

- Lewis Research Center

PUBLIC ORGANIZATIONS

None

The Ministry of International Trade and Industry is one of the prime movers in their government and these offices have direct responsibility for fine ceramics development. Five GIRI Laboratories are heavily involved in the fine ceramics area. The science and technology agency supports relevant work in three major laboratories. Two of these national laboratories are interested in design with and use of advanced ceramics and two are involved in beginning powder development. I have purposely omitted those universities and research foundations or institutes which receive research support in these programs.

As far as outside, or industrial organizations are concerned, the difference is obvious. Hopefully, the group which developed the position paper described this morning, will become the nucleus of an organization similar to the position paper described this morning, will become the nucleus of an organization similar to one of these in Japan.

In closing, may I again express our appreciation for the opportunity to bring to this Committee our views on a significant problem facing a portion of our Nation's industry.

Mr. GLICKMAN. OK. Our next witness is Mr. John Boppert, with the Garrett Turbine Engine Co., and Dr. Ian Macpherson. I would suggest that Mr. Harold Helms of Allison Gas Turbine Operations of General Motors also come up here at the same time because you're all dealing with essentially the same subject matter. And then we'll take you as you go, and then we'll ask questions.

Mr. BOPPART. OK. Once we get the machine on, I think we can hold ours to 15 minutes.

Mr. GLICKMAN. OK.

Mr. BOPPART. All we've got to do is plug the machine in.

Mr. GLICKMAN. Having Ford and GM at the same table probably does not violate any antitrust laws.

Mr. BOPPART. Not if I have anything to do with it. [General laughter.]

Mr. GLICKMAN. Since you both made a little money the last year, I think it's useful that we have successful companies before—

[Pause.]

Mr. BOPPART. If you will just bear with us momentarily there. That's good.

STATEMENT OF JOHN BOPPART, VICE PRESIDENT, ENGINEERING, GARRETT TURBINE ENGINE CO., THE GARRETT CORP.; ACCOMPANIED BY DR. IAN MACPHERSON, DIRECTOR, POWER-TRAIN RESEARCH, FORD MOTOR CO., AND HAROLD E. HELMS, CHIEF PROJECT ENGINEER, VEHICULAR TURBINES, ALLISON GAS TURBINE OPERATIONS, GENERAL MOTORS CORP.

Mr. BOPPART. OK, on to the next one. You've already—we've already identified ourselves.

We are talking about the automotive gas turbine program, as indicated here. (fig. 1)

Our team is made up of Garrett Turbine Engine Co. as prime, with a number of subs, the major being Ford Motor Co. (fig. 2)

The subjects that are covered in our testimony that I will deal with very briefly are, again, foreign ceramic competition, the progress we've made, and some comments from Dr. Macpherson, and generally where we think we're going from here.

I will dwell—I will skip most of the material that we had on foreign competition because it's very similar to that which was presented. I thought just another sidelight might be this, which was shown at a recent Japanese automotive show and illustrates a concept car by a major Japanese manufacturer which has an all-ceramic gas turbine in it and which is advertised as being suitable for near-term production. (fig. 4)

In fact, the sign over—over the exhibit says, "The ceramic gas turbine engine, a powerplant for the near future." And I think it's generally indicative of the very high emphasis placed on ceramic gas turbine development in Japan. (fig. 5)

Moving right along, again I think the same slide was used by the previous speaker. And the only point we wanted to make here is that the Japanese certainly are serious about this. This Japanese Fine Ceramics Association has grown from nothing in 1981 to 175 members today. Most of the members have to do with other than

automobiles, and all of them are devoting a lot more money to this than their current utilizations would indicate. (fig. 6)

The ceramic technology is being very actively pursued in Europe also. United Turbines is running a ceramic gas turbine. ASEA is making ceramic turbine and turbocharger rotors. The other companies indicated there are heavily involved. (fig. 7)

Germany's program is continuing. They've spent about \$50 million through 1983. They have a well-defined go-forward program in which the Government is sharing heavily in the costs. (fig. 8)

Now turning to the AGT101, this has been a year of very significant accomplishment for our program. To date, we have had manufactured by our various vendors over 8,000 of the ceramic parts of our engine that are indicated here. (fig. 10)

We have screened these parts in individual test rigs to operating temperatures as a quality control measure to screen out both defective parts and defective designs. As a result of this work, we've made a number of changes in the basic design in order to adapt the properties of ceramics to the requirements of gas turbine engines.

To illustrate—there is a series of slides here, and we'll just go very rapidly—and the only point we're trying to illustrate is that because of the simple symmetrical configuration of our engine, its assembly is a very easy, straightforward process. Most of the parts that make up the basic engine, the ceramic parts, are fundamentally round, and the process of building the engine is really one of just stacking up the ceramic parts, when you finally get built up to the point where you put the regenerator on and you've got the engine almost assembled. (figs. 12-17)

The other, of course, the main technology area in our program has been the turbine rotor because it is the most highly stressed part. As we began the program, the ability of any of the suppliers to make ceramic turbine rotors was very poor. We had poor quality in terms of the ability to produce these very thin blades on the thick rotors. Often we thought we were very successful if we got a 10 percent useful yield out of a particular batch. (fig. 18)

Within the last year this has improved radically. Our yields in sample batches are up to around 70 percent. The quality in appearance is very good. We've also screened the rotors in thermal rigs in which we operate them to the full temperature.

The culmination in the latter part, or just recently, of all this activity has been that we have assembled our first engine with all of the ceramic parts except the rotor in it. We have run the engine to 2,100 degrees, which is a major milestone on our way to the full temperature of 2,500 degrees.

So the program is making very, very substantial progress at this time.

At this point I would like to turn it over to Dr. Macpherson.

Dr. MACPHERSON. Good morning, Mr. Chairman. I don't wish to add much to our written submission at all. I would like to emphasize the way that over the last 12 months we have been able to see a link between the ceramics technology in this program and the ceramics technology needed for wider application in such things as the diesel. This was referred to yesterday in the DOE submission, and like them, we, too, see this as an important part of this program, the spinoff into other technologies.

Thank you.

Mr. BOPPART. OK. I would like to—can I have the lights off again? Sorry I didn't tell you that.

Just to conclude then, I would like to show you where we are. On the basis of the funding that has existed in the last couple of years, we are a little bit behind schedulewise, though not expenditurewise, not budgetwise, from the original plan. And at this point, we recommend that the original completion date of the end of fiscal year '85 be extended to the end of fiscal year 1986.

We expect that on that basis and on the basis of a recommended funding of about \$10 million per year for the next 2 fiscal years, we will reach the originally anticipated program goals by the end of fiscal year 1986, and we will do so within the originally contemplated contract dollars. (Fig. 20.)

Finally, I would like to remind you that in addition to its automotive application, the kind of technology that we are developing in this program has a very wide application to a number of other areas, as indicated here. (Fig. 21.)

Go ahead.

As a number of people have indicated, the foreign competition continues to be keen and is certainly accelerating. The technology being developed is very valuable to reducing our energy consumption and reducing our need for strategic materials.

Good progress is being made on all aspects of the program. The development of ceramics is proceeding very rapidly, and the demonstration of feasibility in an engine environment is proceeding very satisfactorily, and the resulting technology will have wide applicability.

On the basis of this, then, our closing recommendation is that the programs be continued, with the anticipation of completion of the original goals by the end of fiscal year 1986, and that adequate funds be provided in the next 2 fiscal years to accomplish that.

I thank you, and I think we're available for questions.

Mr. GLICKMAN. OK. Why don't we go ahead and hear what you have to say, Mr. Helms, so that we can deal with these concepts, because I think that much of what you have to say parallels, I am sure, what Ford has said.

Mr. HELMS. Yes, indeed. We have similar objectives and goals, as shown on the first chart that we have here. (Fig. 1.)

I think that I would like to show just these few charts. There are only five. This shows the application and the objectives.

The next chart, please.

This shows our engine on the test stand. We have now accomplished more than 100 hours of testing on that engine. (Fig. 2.)

Next chart, please.

We have made the ceramic components. Many of these components, we were advised, were impossible to make early on at the start of the program. Illustrated on the table over here are many of the ceramic parts, that I would invite you to look at. (Fig. 3.)

Mr. GLICKMAN. I have some experience with those. When I visited the Garrett facility, I think I dropped one, unintentionally.

Mr. HELMS. Shame on you. [Laughter.]

This illustrates our commitment to getting cost out of this turbine. On the left is a part that was originally welded, and we've

now found at Pontiac that we can deep-draw this piece and take probably 85 percent of the cost out of the part. (Fig. 4.)

And the last chart again shows the schedule, much as Mr. Boppart showed a schedule. And we concur with his recommendations and funding levels. (Fig. 5.)

If I may, please, I would like to read just the last page or two of my testimony. I invite you to read the rest of it at your leisure. I think we have a few points we would like to make.

We observe that the success of this program—and, I suggest, of the Garrett program—depends in a large measure on continued favorable results in basic research in the exciting science of materials; specifically, high-performance ceramics, and corresponding advancements in the ability to fabricate these new materials to extremely exacting tolerances.

The AGT 100 program represents much more than developing an engine concept. We and those associated with us are working at the leading edge of technology and, I might add, applicable to military as well as commercial programs. And we're working there with new ceramic components needed to withstand temperatures that would deform some of the most costly and exotic metals we know of—I might add, maybe melt those materials.

Of equal importance, we are deeply involved in manufacturing research in the practical methods of precision forming of component parts to withstand the high rotational speeds without distortion and fracture.

In every respect, research in materials and their fabrication go hand in hand. Ultimately, any material substance is only as useful as our ability to form it consistently, reliably, and economically.

While our ultimate program objective is related to small, lightweight gas turbine engines, we are learning through our research, or what we are learning will be applicable to other power plant configurations, including the diesel, rotary, or Wankel, and the conventional gasoline engine.

We also foresee many other uses where lightweight, high-strength fabricated components will be required.

With respect to application to the turbine, we are extremely optimistic about alternate fuel capability. In this era of heightened energy awareness, and recognizing that petroleum supplies are both finite and insecure, we would be derelict if our research did not comprehend the use of alternate fuels. We have already demonstrated at General Motors the gas turbine's capability to operate effectively on fine pulverized coal, an abundant U.S. energy source.

Testing is also planned later this year using methanol.

Despite our justifiable optimism, we don't want to leave the impression that the research is complete or that the problems remaining are simply developmental in nature. Ceramic component development has not been achieved as quickly as planned, and this is one of the risks that accompanies research-oriented programs.

Nevertheless, we urge no letup in the efforts now underway. There is light at the end of the tunnel. One of our principal associates, GTE, in a letter which is attached to our statement, puts this effort in proper focus. One short paragraph is especially significant:

The market potential and embryonic state of these advanced ceramics is analogous to the situation with superalloys early in their development. In the superalloy

case, specialty metal and engine manufacturing teams were funded by major national research, development and engineering programs. As a result of this concerted funding, the United States still enjoys a dominant world position in the superalloy gas turbine engine market.

Most observers agree, in the international competition—and America wants technical superiority—to win that race demands a cooperative effort on the part of all segments of our society. And Government's role, we believe, is to support industry in high-risk research that otherwise might not be undertaken or perhaps not with the vigor that is required.

In closing, sir, General Motors recommends highly that you continue the AGT 100 and the 101 programs. And that concludes my remarks. Thank you.

Mr. GLICKMAN. OK. I just want to ask you specifically your opinions about the DOE proposal to converge to one contract this year. And assuming at this moment that we don't know what methodology they would use to choose that contract, although they alluded to that yesterday, but that what they propose is giving a consolation prize to the other contractor in some sort of ceramic component development effort—which I think is ridiculous; if you're going to go with one contract, you're going to go with one contractor. There's no reason to spend the money on a consolation prize. Would you agree there?

Mr. BOPPART. The productivity of a consolation prize is somewhat questionable.

Mr. GLICKMAN. What I'm saying, now, my inclination is to want to support two contractors. The question that I had asked, mentioned yesterday to the Department of Energy, however, is that—whether one could work out some increase in the cost share, not necessarily a dramatic increase but something so that both contractors could continue through proof of concept with the money requested by Department of Energy. Is that possible?

Mr. BOPPART. Well, let me comment first to your previous question. I think that we believe very strongly, and I am sure Mr. Helms agrees, that both programs at the present time are in a phase where the benefits of having two programs, having the competitive environment, are very large. Both programs are developing technologies with slightly different technology bases, from slightly different vendors, with slightly different design approaches. And I think it is very clear, if I were able to be impartial, that we are in a phase where the benefits of continuing these dual paths, having the benefit not only of the breadth of approach but, frankly, of the competitive environment, far outweigh the additional costs, if any.

With regard to cost sharing, as we have pointed out in the past, our contractual team is at the present time putting in 60 or 70 cents for every dollar that the Government gives us. Our contract, as opposed to the Stirling one, has no fee.

Nonetheless, I think it is reasonable to recognize that as high-risk technology efforts of this kind come closer to being proved viable and come closer to the transition to development, it has always been our policy in dealing with Government-financed R&D to accelerate our willingness to cost share as the feasibility comes closer to being proven. So I certainly would not rule that out.

Mr. GLICKMAN. Mr. Helms?

Mr. HELMS. I share completely John's statement here. As a matter of fact, in this past year General Motors did, in fact, increase their cost share in this program. And that was not required, incidentally.

Mr. GLICKMAN. Well, what we may want to do is have the staff talk to you a little more. It is my intention to go ahead with two contractors, notwithstanding what the Department of Energy says. But when you compare the fiscal soundness of Ford, General Motors, and the U.S. Government, at least as of the last fiscal year you did better than we did. [General laughter.]

Mr. BOPPART. I would be happy to give you signal results which are not quite that good.

Mr. GLICKMAN. Yeah. Well, you know, I mean I realize it's not permanent, and although from your standpoint I would hope that it is. But I just—I just want to make sure that, given current fiscal realities of both our respective positions, that we might be able to, you know, look at this in some respects without putting all of the risk on you, which is not appropriate right now. And so we'll talk more about this.

But I want to indicate to you all that I would like to keep both programs going. I think that probably a majority of members of this committee on both sides of the aisle would like to do the same thing. But we'd also like to see if we can review this cost sharing thing and discuss it. And from what you've told me today, you're amenable to looking at it. So we appreciate that.

Dr. MACPHERSON. May I just have a word—

Mr. GLICKMAN. Yes.

Dr. MACPHERSON [continuing]. Mr. Chairman. Yes, we, too, think it's important to keep the two projects going. There are very significant technical differences between the two projects, and quite frankly, you cannot develop ceramics if the rest of the engine isn't there moving in step with it. And to say that a partially developed engine can be used to develop ceramics is not really a tenable technical approach.

Second, on the subject of cost sharing, yes, of course, we're prepared to look at it. We do appear to have done very well in the marketplace. Yet unfortunately, we still have to catch up on some of the earlier disasters. But even so, we're prepared to look at it.

Mr. GLICKMAN. Our problem is we have a disaster right now in the operation of this Government. You know, I want to try to be as responsible as I can. And I have been a strong advocate of both programs, the Stirling and this one. But, you know, I have to also deal with fiscal realities and not say to everybody, "I want to cut your program but not mine because I chair the subcommittee." So—

Mr. HELMS. I would like to just comment, sir, that the recommendations of Dr. Mueller and reapportioning the funding amongst Government agencies might be a subject of concern also.

Mr. GLICKMAN. I agree.

Mr. BOEHLERT.

Mr. BOEHLERT. Just one question, Mr. Chairman. I am mindful of the time constraints.

I would like to ask Mr. Boppart and Mr. Helms both if you're satisfied that the current nondestructive testing procedures are adequate to determine a product is safe.

Mr. HELMS. I am not satisfied, sir. I think we need indeed more progress. And some of the programs that are being proposed and initiated will be very helpful in that direction, such as the ceramic initiative programs at NASA-Lewis and Oak Ridge.

Mr. BOEHLERT. Thank you.

Mr. BOPPART. Did your question address safety?

Mr. BOEHLERT. Yes.

Mr. BOPPART. I think probably the point should be made that the use of ceramics in gas turbines is a giant step in the direction of safety itself because of the extremely low mass of the high-speed rotating parts and because of the nature of their failure, which is to turn to powder. So I—

Mr. HELMS. It's a bucket of sand instead of metal fragments.

Mr. BOPPART. Yeah. Really, there basically is no real safety issue. There is, as Gene has indicated, there is a continuing need to improve the nondestructive testing simply from a produceability and economy viewpoint, and a lot of progress is being made. It's marching along in parallel, I think, in a very satisfactory manner.

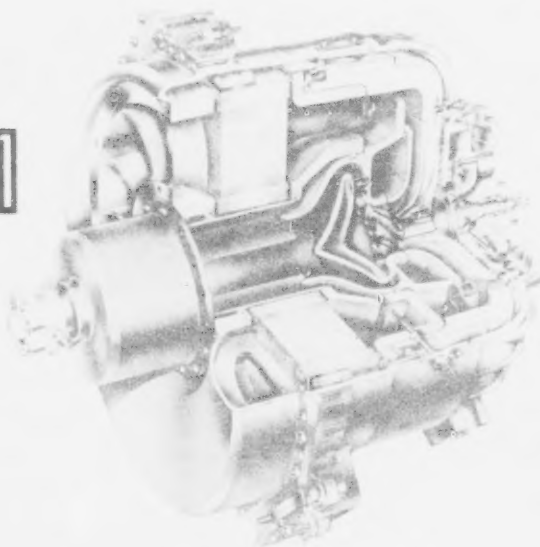
Mr. BOEHLERT. Thank you very much.

[The prepared statements of Mr. Boppart and Mr. Helms follow:]

TESTIMONY BEFORE
THE SUBCOMMITTEE ON TRANSPORTATION,
AVIATION AND MATERIALS
OF THE
COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

PROGRESS REPORT
GARRETT/FORD
AUTOMOTIVE
GAS TURBINE PROJECT

AGT101



22 FEBRUARY 1984

JOHN BOPPART
VICE PRESIDENT, ENGINEERING
GARRETT TURBINE ENGINE COMPANY

DR. IAN MACPHERSON
DIRECTOR, POWERTRAIN RESEARCH
FORD MOTOR COMPANY



GARRETT TURBINE ENGINE COMPANY
A DIVISION OF THE GARRETT CORPORATION
PHOENIX, ARIZONA

JOHN BOPPART

VICE PRESIDENT, ENGINEERING

Education

B.S. in Mechanical Engineering, California Institute of Technology, 1952

M.S. in Mechanical Engineering, California Institute of Technology, 1953

Work History

1957 to Date: Garrett Turbine Engine Company

- Vice President, Engineering
- Director of Engineering
- Assistant Director of Engineering, Power Systems
- Assistant Director of Engineering, Pneumatic Systems
- Chief of Pneumatic Control Systems
- Senior Project Engineer, Pneumatic Actuation Systems
- Project Engineer, Pneumatic Control Systems
- Assistant Project Engineer, Advanced Power Generation Systems
- Senior Systems Engineer, Systems Support Group

1953 to 1957: AiResearch Manufacturing Company of Los Angeles

- Preliminary Design Engineer
- On loan to Advanced Design Group, ANP Project, Oak Ridge National Laboratory (1956)

Responsibility/Experience

Mr. Boppart currently is responsible for all engineering activities for Garrett Turbine Engine Company.

As Assistant Director of Engineering, Mr. Boppart was responsible for all engineering activities associated with all AiResearch Power Systems products. Prior to this, he was similarly responsible for all AiResearch Pneumatic Systems products.

All engineering functions involving the Power Systems and Pneumatic Systems product lines were under his direction including engineering estimates through design, development, and qualification, and the production liaison activities during the follow-on production deliveries.

Mr. Boppart's prior experience also includes work in various capacities of engineering on pneumatic valves and controls, air motor pneumatic actuation systems, missile and space control valves, space power systems, gas turbine auxiliary power systems, and aerospace environmental control systems.



IAN MACPHERSON

Director — Powertrain Research Laboratory
Ford Motor Company

Education

B.S. in Physics — University of Manchester, England, 1951

M.S. — Cosmic Ray Physics

PhD. — University of Manchester, England, 1952/1955

Work History

1971 to Date: Ford Motor Company

- Director, Powertrain Research Laboratory
- Chief Engine Engineer, Truck Operations, Ford of Europe
- Executive Engineer, Truck Operations, Ford of Europe

1955 to 1971: Rolls Royce Ltd., Aero-Division, England

- Assistant Chief Research Engineer, Combustion and Turbine Systems
- Head of Advanced Research Laboratory
- Section Head, Gas Dynamics Research
- Project Engineer, Submarine Nuclear Reactor Project
- Project Engineer, Combustion Research

Responsibility/Experience

Dr. Macpherson is responsible for all activities within the Powertrain Research Laboratory of the Ford Motor Company, with particular emphasis on future engines and transmissions of relevance to automotive and tractor systems, including alternative fuels.

As Chief Engine Engineer, Truck Operations, Ford of Europe, he was responsible for diesel engine design and development for commercial vehicles. This covered advanced engineering, development of new products and close liaison with production and field activities, including industrial engines.

Work at Rolls Royce covered a span of technologies, ranging from nuclear reactors for submarine propulsion; gas dynamics and combustion at hypersonic conditions; materials and basic physics research; to line responsibility for the combustion and turbine technology embodied in all Rolls Royce gas turbines.



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Mr. Chairman and members of the subcommittee, my name is John Boppart (Figure 1). I am Vice President of Engineering for Garrett Turbine Engine Company, a division of the Garrett Corporation (a Signal Company). I would like to introduce Dr. Ian Macpherson, Director, Powertrain Research of Ford Motor Company. Dr. Macpherson will join me today in presenting this testimony.

Garrett and Ford Motor Company are working together on the Advanced Gas Turbine (AGT101) Program under contract to the Department of Energy and NASA (Figure 2). Garrett is the prime contractor with major support from Ford. We have other major subcontractors in this program such as Carborundum Company, Corning Glass Company, and AiResearch Casting Company (a Garrett Division).

The AGT101 team is developing high-risk, long-range technology for advanced automotive gas turbines for future automotive and other power plants. Major emphasis of the

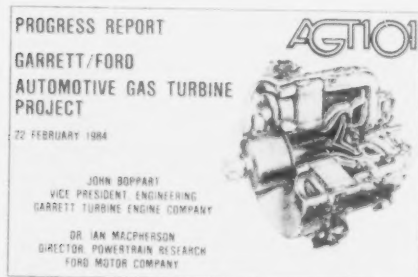


Figure 1. Testimony Before the Subcommittee on Transportation, Aviation and Materials.

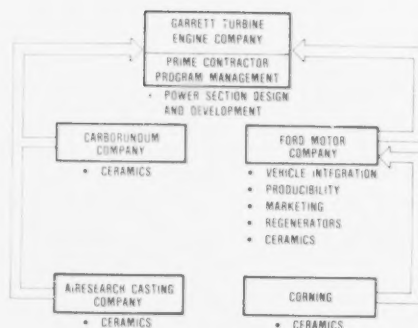


Figure 2. Garrett/Ford AGT101 Program Team.

program is to develop ceramic component technology for gas turbine engines.

Ceramics offer many advantages to the gas turbine and other power plants. Foreign ceramic development is proceeding in earnest.

In today's testimony, I wish to focus on the foreign ceramic competition as we see it, the AGT101 team progress and where it leads us in the future, and our recommended go-forward plan (Figure 3).

- FOREIGN CERAMIC COMPETITION
- AGT101 PROGRESS
- FORD REPORT
- WHERE ARE WE GOING
- RECOMMENDED GO-FORWARD PLAN

Figure 3. Today's Focus.



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Ceramics are essentially nonmetallic, inorganic materials that can replace many of the strategic materials currently being imported from foreign sources for use in manufacturing today's engines. Ceramic elements are readily available within the United States and other friendly nations. Silicon and nitrogen are elemental constituents of ceramics and there is an inexhaustible supply at low cost. Many of the strategic materials used in gas turbines are being depleted and would not be available in automotive production quantities. In any event, cost of these strategic materials is not competitive for automotive application.

FOREIGN CERAMIC COMPETITION

Stiff foreign competition is developing, especially in Japan, in advanced ceramic technology for turbine engines and a variety of other applications. The Japanese government and industry have both identified ceramics as a focused development effort for the 1980s to yield profitable high technology industries in the 1990s and to help decrease energy consumption.

During October of 1983, members of Garrett and Ford visited Japan and participated in an International Symposium on Ceramics for Heat Engines. Field trips to leading Japanese ceramic companies were also allowed. In addition, a visit to the International Gas Turbine Conference was also a part of the trip. A major Japanese automobile manufacturer displayed a ceramic gas turbine in a prototype car (Figure 4). The heading over the display (Figure 5) reflected "Ceramic Gas Turbine Engine - a powerplant for the near future"; a significant statement for a technology we consider long-range and high-risk.

Substantial reduction in energy consumption in Japan has already been credited to ceramics. Development of a new silicon nitride base refractory brick composition allowed adoption of continuous casting in the steel industry, resulting in an 85-percent reduction in energy needs. Such success has stimulated further accelerated R&D. To quote Kumo Nakayima, Chief of the Fine Ceramics Office of the Ministry of International Trade and Industry

- JAPANESE PROTOTYPE CAR
 - REAR MOUNTED DUAL-AXIS 100 HP CERAMIC GAS TURBINE
 - OPERATING TEMPERATURE = 2462°F
 - CERAMIC COMPONENTS
 - ▢ TURBINE BLADES
 - ▢ TURBINE SHROUD
 - ▢ COMBUSTION CHAMBER LINES
 - ▢ HEAT EXCHANGER CORE



Figure 4. Foreign Ceramic Competition is Developing.



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Figure 5. Japanese Gas Turbine Engine.

(MITI), "According to a Japan Fine Ceramics Association survey of member companies, R&D expenditures for fine ceramics accounted for 20 to 50 percent of their total R&D outlays, despite the fact that in many of the companies fine ceramics accounted for less than 1 percent of total sales in 1981." It is interesting to note that the Fine Ceramics Association was formed in 1981 and as of April 30, 1983, had 175 member companies, only 41 of which were ceramics companies (as shown in Figure 6).

All indications are that the Japanese are seriously pursuing advanced ceramic devel-

BUSINESS	NUMBER OF FIRMS
• CERAMICS	41
• CHEMICALS	32
• ELECTRIC APPLIANCES	25
• STEEL AND NON-FERROUS METALS	23
• MACHINERY	23
• AUTOMOBILES	7
• HEAVY INDUSTRIAL ENGINEERING	7
• OTHERS	17
TOTAL	175

Figure 6. Japanese Fine Ceramics Cover Broad Business Base.

opment and are making progress. Their programs appear well-planned, adequately funded, and better staffed than typical U.S. programs. As an example, a research manager for one Japanese ceramics company stated that he had a staff of 80 engineers and technicians working exclusively on silicon nitride and silicon carbide materials. This represents a substantial commitment considering that their current production is in oxide ceramics, and they are only making prototype parts of silicon nitride and silicon carbide. Garrett is not aware of a ceramics company in the U.S. with an equivalent level of R&D effort in advanced ceramics.

Garrett has had an opportunity to evaluate prototype components from Japan under the AGT program and under two internally-funded programs, one involving the integration of ceramic rotors into turbochargers and the other the employment of ceramic stators into an auxiliary power unit. In general, the Japanese deliveries have been more prompt than U.S. ceramics companies and the quality of components has been superior.

Ceramic engine component technology is also progressing in Europe. United Turbines of Sweden has reported operating ceramic components in a turbine engine installed in a Volvo (Figure 7). Included was an integral axial rotor manufactured by ASEA of Sweden by hot isostatic pressing. ASEA has also manufactured radial turbocharger rotors to near net shape with high yield by the technique and claims that the approach is suitable for production.

The Federal Republic of Germany has conducted an active Government/Industry



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- UNITED TURBINES OF SWEDEN CERAMIC GAS TURBINE IS BEING TESTED BY VOLVO
- ASEA OF SWEDEN — CERAMIC TURBINE WHEELS AND TURBOCHARGER ROTORS
- VOLKSWAGEN TESTING CERAMIC TURBOCHARGER ROTORS AND GAS TURBINE COMPONENTS
- MTU (MOTEREN UND TURBINEN-UNION) TESTING CERAMIC GAS TURBINE COMPONENTS
- DAIMLER-BENZE DEVELOPING CERAMIC GAS TURBINE FOR "CAR 2000" RESEARCH PROGRAM

Figure 7. Ceramic Technology is also Progressing in Europe.

ceramics program since 1974 (Figure 8). It has involved Government laboratories and universities, plus major ceramics fabrication companies and engine companies including Volkswagen, Daimler-Benz, and MTU. The industry activities are funded 50 percent by the German Government.

AGT101 Progress

Now I would like to discuss the significant progress the AGT101 team has made. The AGT101 (Figure 9) is a 100-horsepower engine

- \$50 MILLION SPENT THROUGH 1983 ON VEHICULAR GAS TURBINE COMPONENTS
- FOLLOW-ON PROGRAM WAS INITIATED
 - IMPROVE RELIABILITY
 - POWDERS, PROCESSING, NDS
 - ADDITIONAL CERAMICS MATERIALS
 - OTHER APPLICATIONS
- GOVERNMENT/INDUSTRY SHARE COSTS
- RESEARCH INSTITUTES FULLY FUNDED

Figure 8. German Ceramic Program to Continue.

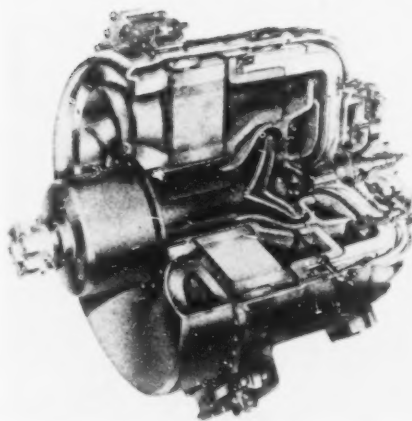


Figure 9. AGT101 Power Section.

that operates at speeds to 100,000 rpm and temperatures as high as 2500°F. The high operating temperature is made possible by the use of uncooled ceramic components. This higher temperature contributes to the outstanding fuel economy the AGT101 will be capable of providing future automobiles.

Shown in Figure 10 are the ceramic parts being provided by our team. To date, over 8,000 of these parts have been fabricated. Note that the AGT101 ceramic parts are symmetrical in shape which allows ease of fabrication, reduced stresses, and eventual low cost. Most of the more difficult components have been made by more than one contractor, by different methods, and in some cases of different ceramic materials.

All ceramic structural parts have been successfully tested individually to 2100°F in test



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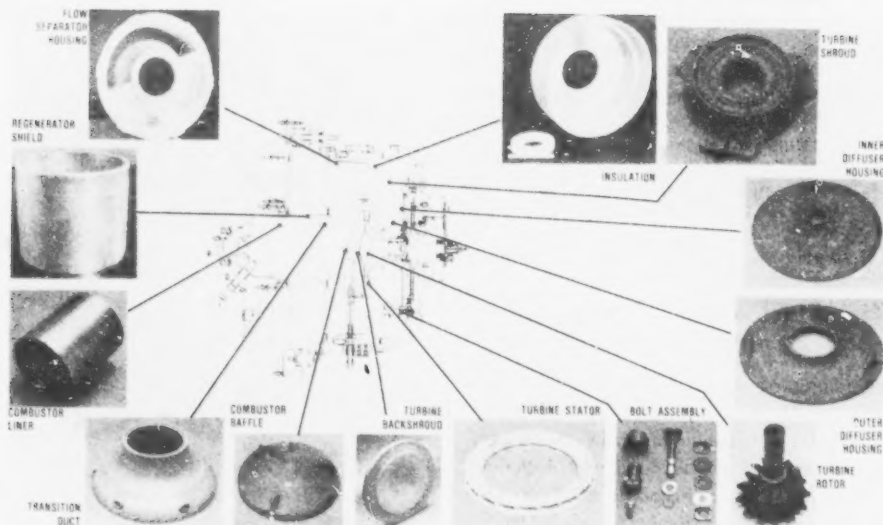


Figure 10. AGT101 Ceramic Components.

rigs to simulate operating environments and to screen out poor quality parts. Many of the parts have been significantly modified to ease fabrication and reduce stresses to avoid failures.

When the individual tests have qualified the parts, a complete set is then assembled into a ceramic module (Figures 11 through 17) for test in the ceramic structures test rig. This rig simulates an engine environment as closely as possible but does not incorporate a rotating assembly. This test is a further screening operation to eliminate parts that could fail in the engine test bed.

Successful tests of the complete ceramic module were accomplished to 2000°F in 1983.



Figure 11. Ceramic Structures Assembly in Process.



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Figure 12. Ceramic Turbine Shroud Module Assembled.

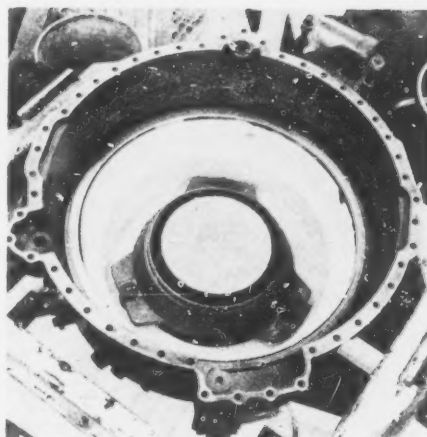


Figure 14. Install Back Shroud.

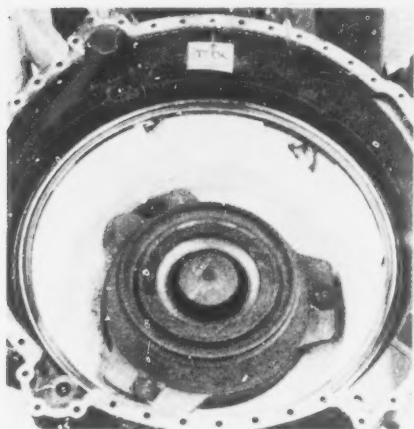


Figure 13. Install Module in Compressor Housing.

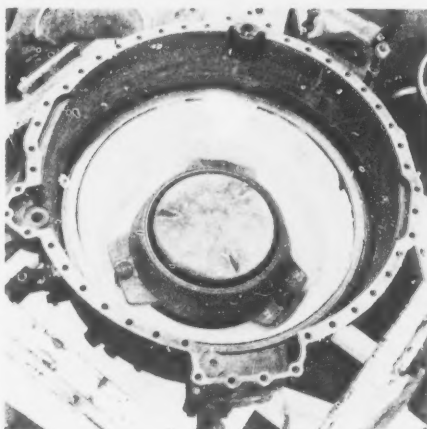


Figure 15. Install Combustor, Baffle.



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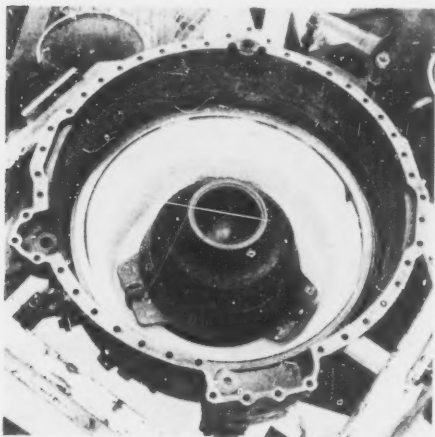


Figure 16. Install Transition Duct.

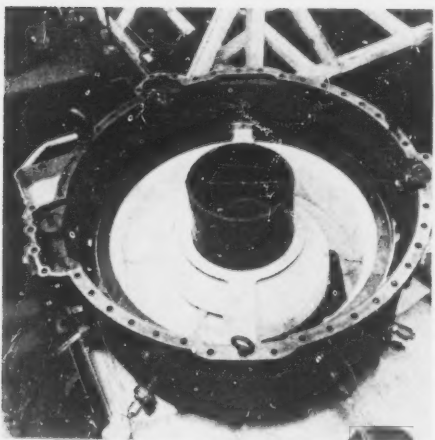


Figure 17. Install Flow Separator Housing and Regenerator Shield.

Simulated engine starts and shutdowns were accomplished.

Let me emphasize that ceramics must be developed in a manner described above in order to successfully and with minimum expense and time develop them for applications such as gas turbines. Ceramics are in the early stages of development, as metals were many years ago and must be developed in a step-by-step cooperative approach. To be successful, ceramic parts must be evaluated in the engine environments in which they will be operating.

The ceramic turbine (rotor) has been one of the most challenging tasks of the AGT101 program. Ford and AiResearch Casting Company are developing the rotors (Figure 18).



Figure 18. AGT101 Ceramic Turbine Rotor.



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The rotors are cold spin tested to 115,000 rpm as an initial proof check. They are then hot spun in a test rig to simulate engine operating conditions (Figure 19). If the rotors successfully pass these tests, they are then ready for engine testing.

During the initial years of the program, when the contractor attempted to fabricate the rotors, the yield (those successfully fabricated) was very low (approximately 10 percent). Within the last year this yield has increased to nearly 70 percent.

The first engine test with all of the ceramic structural parts is underway. The start and shutdown transients are purposely slow and the operating temperature restricted to 2100°F. The test represents a significant milestone in the program.

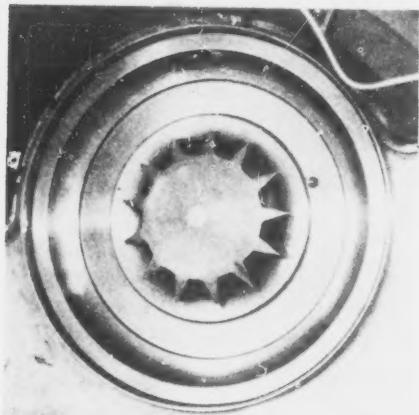


Figure 19. Turbine Rotors are Thermally Cycled Prior to Engine Testing.

MP-90033

The successes we have accomplished thus far are very encouraging, however, these successes represent only the beginning in the evolution of ceramics. Our testing has been minimal and the quality of many of the ceramic parts has been poor; both must be greatly enhanced before industry is ready to carry the technology forward to production.

Dr. Macpherson will now make his statement before I provide the concluding remarks.

FORD REPORT

Mr. Chairman and members of the subcommittee, my name is Ian Macpherson and I am the Director of the Powertrain Research Laboratory of the Ford Motor Company.

Competitive Actions Overseas — Ceramics for Prime Movers

As you have seen from today's earlier presentation describing some of the activity in Japan and other overseas locations, we at Ford share the views of John Boppert on the impressive, rapid growth of active research and development in this important field.

AGT101 — Status Report

My comments will fall under the following headings:

- Future Engine Technology
- Progress on the AGT101
- Wider Applications of Ceramics

Future Engine Technology

The subcommittee is well aware that the pace of technology development in engines is not diminishing. At Ford, we aim to keep at the



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forefront of research on spark ignition (gasoline), diesel and other combustion engines, as well as other unconventional devices such as electric vehicles.

Since last reporting to the subcommittee, an upsurge of activity has become apparent on a worldwide basis in a number of advanced areas, including in particular the so-called adiabatic diesel. In its most advanced form, this concept makes extensive use of ceramic materials to reduce waste heat from the engine. There is consequently a gain in useful output for a given supply of fuel, on-the-road fuel consumption is reduced and this version of the diesel has potential, in the long term, to compete with the gas turbine. Interestingly, both the advanced gas turbine and the advanced diesel depend on the needed breakthrough in ceramics technology that is now the prime focus of the AGT101 program. The gas turbine continues to have greater potential for burning alternative or deteriorated fuel, for lower noise and vibration and for lower costs associated with the simplicity of its design when compared to the elaborate systems needed by the advanced diesel concepts. As we have stated in the past, the key lies in the achievement of satisfactory ceramic components for operation at the high temperatures of the gas turbine.

Progress on the AGT101

Ford is responsible for the large regenerator (heat exchanger), the gas seals on this regenerator, and is working on the ceramic turbine rotor and stator assembly.

Regenerator and Seals —

Our close collaboration with Garrett in the development and testing of these

components at Phoenix has led to good progress on the choice of materials and on the development of cooled seals, a technology not previously attempted.

Ceramic Turbine Rotor —

The turbine rotor is the most challenging ceramic component in the entire engine. The high rotational speeds impose loads of 17 tons on the center of the rotor. There are major changes in the shape of the part, from the massive hub to the fine curved blades on the periphery.

The single turbine rotor of the AGT101 has been deliberately placed at the leading edge of design and processing technology because in this way the potential for a low cost end product is maximized.

1983 started with promising results in the fabrication of rotors. However, the laboratory scale process proved to be erratic and further improvements are required. We have continued these efforts and, in addition, we have also introduced an entirely new way of making this most difficult part.

Ceramic Turbine Stator —

The ceramic stator ring, produced as a monolithic part, is now being produced repeatedly and reliably for experimental tests. A sample is on view in our exhibits.

Wider Applications of Ceramics

As I mentioned earlier, this subject is receiving growing attention around the world. The fabrication processes and other aspects of ceramic technology that have been assessed



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and improved in the AGT101 activity up to this point will continue to contribute to more than just the automotive gas turbine. We at Ford welcome the continuation of the AGT101 activity as a technology development program. In last year's report, I mentioned how the AGT101 ceramics activity has led to a spin-off into cutting tools. We are now seeing a link developing between the AGT101 technology and advanced diesel and gasoline engines. We are not alone in this. We conclude that the potential for the beneficial application of ceramics continues to grow, beyond the immediate target of the AGT101.

John Boppert will continue.

WHERE ARE WE GOING?

The AGT101 program accomplishments have been made during a period of budget

reductions, constraints, and uncertainties. When the program was reoriented in 1981 and funding reductions took place, a go-forward program was recommended to this committee. That program has been followed since that time and is consistent with the program schedule shown in Figure 20. The long-range, high-risk technology elements of the power section are being brought forward. Component testing, followed by engine test bed evaluation, is leading to a final demonstration of AGT101 power, performance, emissions and multi-fuel capabilities on an engine dynamometer. The ceramic parts will have been tested in the engine by that time and initial judgements as to their suitability for mass production in the early 1990s will have been made.

Ford, as well as other companies, has new transmissions under development that will

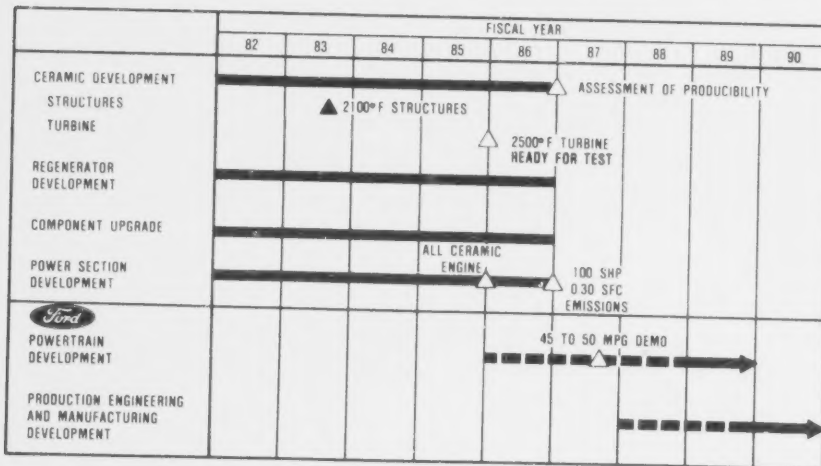


Figure 20. Restructured AGT101 Program.



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further improve the AGT101 powertrain fuel economy. The original goal was 42.8 mpg (Combined Federal Driving Cycle) in a 3,000 pound car; however, these new transmissions provide the potential of increasing this fuel economy goal to 45 to 50 mpg for vehicles that we expect could emerge from the pilot production phase beyond this technology program.

We have been strong advocates that the AGT101 program goals should have been achieved by the end of 1985. At last year's testimony, we reviewed the budget uncertainties experienced during the program and emphasized that \$12 million would be needed in FY84 and again in FY85 if the program goals were to be achieved on schedule. These dollars were needed at the contractor level (after Government expenses) or the program would need to slip into FY86. That level of funding was not available to our team in FY84. As a result, we now wish to recommend that the program be extended one more year — to the end of FY86. We also recommend that \$10 million be provided in both FY85 and FY86 at the contractor level.

Before concluding, I would like to remind you that the AGT101 technology is applicable to many other future applications (Figure 21). For example, the AGT101 is being evaluated as a dispersed solar thermal generator set; this approach could reduce the country's demand for fossil fuel. Multi-fueled generator sets for potential military use are being considered, as are tractors, construction equipment, and trucks, which are all candidates for AGT101 power plants. Aircraft power plants and auxiliary power units also are potential applications.

- DISPERSED SOLAR THERMAL GENERATOR SETS
- MULTI-FUELED GENERATOR SETS
- TRACTOR POWER PLANTS
- CONSTRUCTION EQUIPMENT ENGINES
- AIRCRAFT PROPULSION
- AUXILIARY POWER UNITS
- DIESEL COMPONENTS
- TURBOCHARGERS
- CUTTING TOOLS

Figure 21. AGT101 Technology is Applicable to Many Applications.

Other technology spin-off potentials involve adiabatic diesel engines, diesel particulate traps, turbochargers, cutting tools, and reduced friction components.

CONCLUSIONS AND RECOMMENDATIONS

The current AGT101 program is an advanced, long-range, high-risk power plant technology program that is consistent with administration guidelines for government support. The technology being developed will aid in reducing our country's energy consumption and dependence on foreign oil (Figure 22). The program also provides the technology base to potentially reduce our dependence on strategic materials; these materials are being depleted worldwide, are expensive and many are supplied by foreign nations. The foreign government subsidized competition is keen and must not be allowed to further degrade our industrial marketshare and balance of trade.



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- FOREIGN COMPETITION IS KEEN
- TECHNOLOGY BEING DEVELOPED WILL REDUCE COUNTRY'S ENERGY CONSUMPTION AND DEPENDENCE ON FOREIGN OIL
- WILL POTENTIALLY REDUCE NEED FOR STRATEGIC MATERIALS
- GOOD PROGRESS BEING MADE
 - CERAMICS
 - MULTI-FUEL CAPABILITY
 - HEAT RECOVERY
 - LOW EMISSIONS
 - IMPROVED EFFICIENCY COMPONENTS
- TECHNOLOGY APPLICABLE TO MANY APPLICATIONS

Figure 22. AGT Program Deserves Support.

The AGT101 is a test bed for technology advancement in the areas of ceramics, multi-fuel capability, heat recovery, and other performance improvements. Ceramics offer many advantages for future power plants, such as lightweight, low cost constituents available within our country, and from improved engine efficiency.

We recommend that the AGT101 program be completed by the conclusion of 1986 and that adequate funds be provided in FY85 and FY86 to allow current milestones to be accomplished (Figure 23); this would allow industry to carry the technologies forward toward production in a timely manner.

Thank you for the opportunity to address the committee once again. We are proud of what we have done, and with your help can do a lot more.

- AGT101 PROGRAMS BE COMPLETED BY END OF 1986
- ADEQUATE FUNDS BE PROVIDED IN FY85 AND 86 TO ALLOW PROGRAM MILESTONES TO BE ACCOMPLISHED

Figure 23. We Recommend...

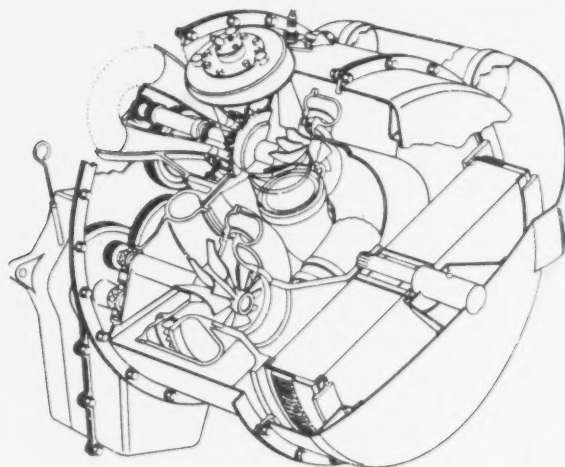


Allison
GAS TURBINE OPERATIONS
General Motors Corporation
P.O. Box 420
Indianapolis, Indiana 46206-0420



EDR 11719

**Testimony of
General Motors Corporation
on
Department of Energy
Advanced Gas Turbine Technology Contract
to the
House Subcommittee on Transportation,
Aviation and Materials
of the
Committee on Science and Technology**



**presented by
Harold E. Helms
Chief Project Engineer--Vehicular Turbines
Allison Gas Turbine Operations
Power Products and Defense Operations Group
22 February 1984**



Allison
GAS TURBINE OPERATIONS
General Motors Corporation



Mr. Chairman, I am Harold Helms, Chief Project Engineer for Vehicle Turbines at the Allison Gas Turbine Operations of General Motors Corporation. I am here to present a status report on the "Advanced Gas Turbine Technology Project"--a research program supported by funding from the Department of Energy and contracted through the NASA Lewis Research Center.

Today, I will give you a brief review of the project, summarize our recent progress and review briefly our optimistic outlook for the future of the technology we are pursuing.

The Allison Advanced Gas Turbine Project

The DOE sponsored the Advanced Gas Turbine Technology Project (AGT 100) with General Motors beginning on October 1, 1979, as part of DOE's on-going transportation program to develop fuel efficient and environmentally acceptable passenger car power plants.

The goal of the program is to develop an experimental advanced gas turbine that will significantly improve fuel economy over present conventional spark-ignition engines.

GM entered the project with an ambitious goal--to develop a gas turbine powertrain system that would demonstrate:

1. Fuel economy of 42.5 miles per gallon based on the EPA test procedure, with vehicle drivability and performance comparable to vehicles equipped with a spark-ignition engine.
2. Gaseous emissions and particulate levels that were lower than EPA-defined research objectives, and total particulate emissions using diesel fuel No. 2.
3. That the turbine engine could effectively use a variety of alternate fuels.



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GAS TURBINE OPERATIONS
General Motors Corporation



These objectives and goals are illustrated in Figure 1 which shows two current automobiles which could use the turbine engine from this project. To help achieve this ambitious goal, General Motors assembled a corporate team to conduct the AGT 100 project. Allison Gas Turbine Operations is the project manager and engine developer. Pontiac Motor Division is responsible for powertrain installation, and for productivity and cost analysis. Major subcontractors are Carborundum Company (Niagara Falls, NY) for silicon carbide engine components, Corning Glass Works (Corning, NY) for aluminum silicate regenerators and GTE Laboratories (Waltham, MA) for silicon nitride turbine engine rotors.

Mr. Chairman, I would now like to focus on the importance of the AGT 100 project. While General Motors has made significant progress in fuel economy and emission control, our work is not done. If America is to become energy-sufficient and avoid the fuel crunches that hit twice in the 1970s, research and development of new technologies must continue. We are all aware that the supply of fossil fuel is not infinite. We cannot afford ourselves the luxury of becoming hostages again to the politically volatile Middle East. Continuation of the AGT 100 project is consistent with this national priority.

We should remain mindful that alternate fuels are becoming more and more popular, with millions of dollars being spent on research and development to bring these fuels to the marketplace. When these fuels become available, we must be prepared with the technology to use them. A key attribute of the advanced gas turbine engine is its ability to burn alternate fuels.

Continued research in the field of ceramics is critical as evidenced by the increased emphasis placed on this new material technology by foreign competitors. Today U.S. leadership in ceramic engine technology is being challenged by foreign competition. Other nations have established aggressive industrial/government/university programs. These nations have become worthy competitors and their progress has been impressive. Therefore, if America is to maintain its leadership in new technology, it is critical that federal funding of the AGT 100 project continues. Reduced funding would seriously risk staff-down of highly skilled R&D project teams which has taken General Motors and others



Figure 1. Objectives and AGT 100 vehicles.



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years to assemble and train. We believe such action would not be in the national interest.

Turning now to the specific technologies of the program, these two are of critical importance. They are the "ceramic components" and "small scale turbine aerodynamics." Significant progress has already been demonstrated in these technologies, but there are research challenges that remain to be met to achieve fully the project objectives.

Ceramic Turbine Components

It is necessary that cost-effective ceramic components with high temperature capability replace the prohibitively expensive superalloy metals currently used in gas turbines components. Superalloy costs are prohibitive because they contain significant levels of strategic materials such as cobalt, chromium, nickel, molybdenum, tungsten, and manganese. None of these costly, strategic materials are found in the silicon carbide, silicon nitride, oxides, and silicate components being developed in the AGT 100 project. One of the most important attributes of ceramic materials we are studying is their high temperature capability. These new materials allow us to operate the turbine at more than 500°F higher turbine inlet temperature than is possible with superalloy metals, which in turn raises the efficiency of the engine.

In addition, our research into new processing methods is establishing reliable and economic production methods.

Aerodynamics

Small scale turbine aerodynamics are important because the automotive gas turbine engine has smaller components than ever before employed in a high performance turbine engine. Simultaneously, the automotive application requires high aerodynamic component efficiencies over a broad power range, with the highest efficiency required at partial speed and power conditions. The average automotive gas turbine power usage is 14 hp (for this 100 hp engine) and most automobiles never use maximum power, since it is incorporated for accel-



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eration, hill climbing, and other emergency power operations. This contrasts with aircraft, industrial, and heavy duty turbine engines, which operate predominately at 50% to 100% power level, but do not have similar acceleration and other emergency power requirements.

Adequacy of Technology Data Base

Heat engine experience has shown that component technology is only valid when proven in actual engine operational environment. This fact of development has been obvious in all engines because of the inability to duplicate in other ways the unique transient operating characteristics of an actual engine. Moreover, we are unable to produce working interrelationships between components associated with aerodynamics, heat transfer, control and mechanical factors. For these reasons, proof of concept engines complimented with rigs, carefully chosen for screening and proof testing, are included in this project to prove that new ceramic and aerodynamic component technologies have been established in sufficient depth for subsequent applications. Figure 2 is a recent photograph of the AGT 100 engine on the test stand in Indianapolis. This engine weighs less than 300 lb, develops 100 hp, has two shafts, is regenerative--that is, it recovers waste exhaust heat--and is compatible with any type of transmission--manual, automatic or continuously variable. The engine and accessory arrangement can be used interchangeably to replace current General Motors spark ignition engines in mid-size automobiles (approximately 3000 lb weight class). Our assessments of reliability, performance, control and cost trade-offs have favored the two-shaft gas turbine engine for vehicle applications where constantly changing power requirements are placed on the powertrain.

Project Status

1983 has been a year of significant achievement. Some of the highlights of 1983 are:

- o further advances in ceramic component processing at ceramic component suppliers

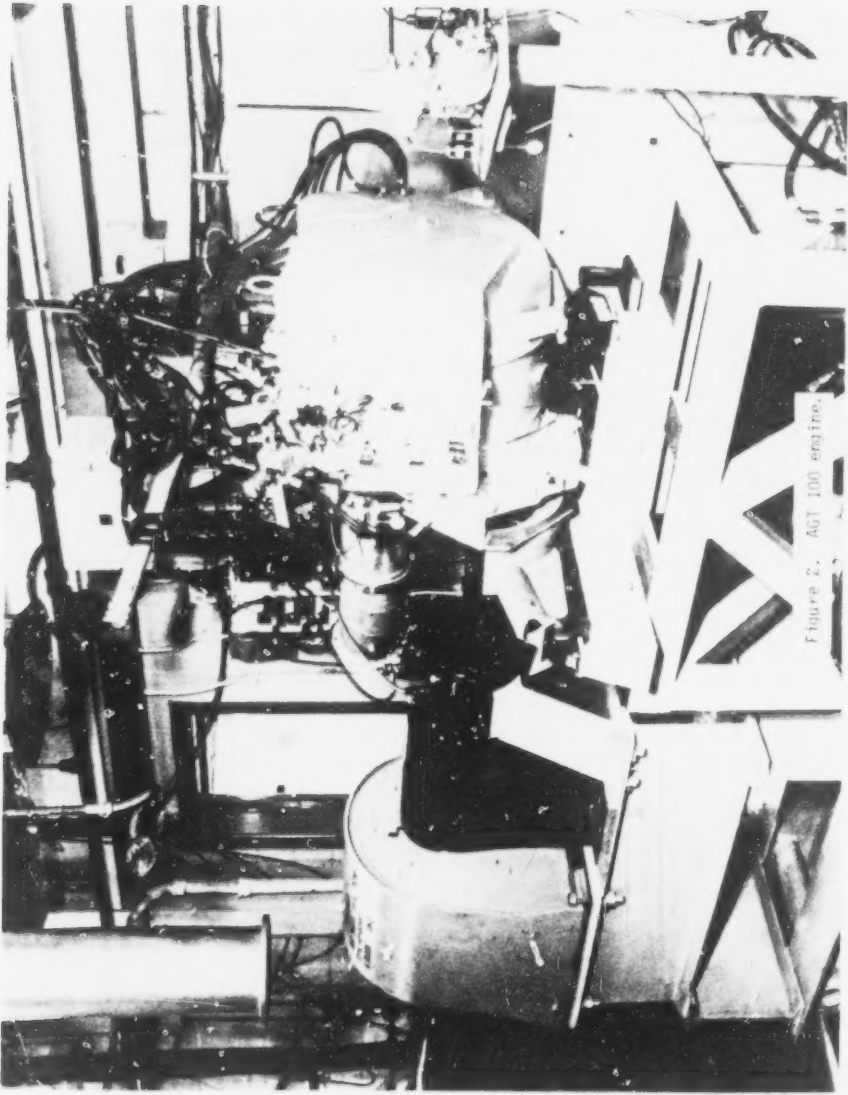


Figure 2. AGT 100 engine.



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- o nine ceramic components were successfully engine tested
- o engine testing proving a reliable engine test bed for future, improved ceramic component evaluations and the potential to achieve project objectives for performance, emissions and multi-fuel capability
- o three new rigs were installed and are operational for improved component screening and proof testing
- o two successive twenty-hour engine tests with turbine inlet temperatures up to 2000°F
- o re-assessment of ceramic supplier capabilities worldwide and new ceramic component suppliers acquired
- o first hand evaluation of Japan's "fine ceramic" projects
- o participation in technical society meetings and on advisory boards for Ceramics
- o new Non-destructive Evaluation (NDE) methods being applied on ceramic components
- o improved design methods implemented for AGT 100 components
- o Pontiac demonstrated feasibility of a low-cost sheet metal regenerator housing on the AGT 100

External to the AGT 100 project but within General Motors these additional ceramic materials and alternate fuels activities occurred:

- o An automotive gas turbine successfully ran on dry micronized coal at General Motors Engineering Staff (Ref: ASME paper 83-GT-183)



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o A General Motors diesel engine ran without a water cooling system and with ceramic and ceramic coated parts.

o The AGT 100 was studied and found to be compatible in our new Pontiac Fiero using its existing engine transmission

More than 1300 silicon carbide rotors were made in 1983 to achieve a nearly optimum injection molding and sintering process. Current rotors being made meet dimensional requirements and are nearly meeting requirements for survivability in production. This progress is considered excellent in view of the long normal development cycle to bring a new material from the laboratory, through complex geometries to a component feasible for production. Figure 3 shows all of the AGT 100 ceramic components that are ready for engine evaluations in 1984.

Engine testing accomplished in 1983 has shown 26 hp at the designed 2000°F turbine inlet temperature which is over 50% of the designed value. This accomplishment combined with two successive twenty hour engine runs shows that this completely new engine concept can become a reliable demonstrator of new technologies as well as being capable of meeting the AGT 100 project performance goals.

To illustrate the General Motors' commitment to meeting production cost goals, Figure 4 shows a single piece sheet metal AGT 100 regenerator cover made by Pontiac. This deep drawn cover made of the SAE 4130 material was not thought to be possible at the beginning of this project. It will replace the original design which was made of seven separate parts welded together.

1984 promises to be an even more rewarding year with anticipated accomplishments to include:

o additional advances in ceramic component processing--from old and new suppliers

AGT 100 CERAMIC COMPONENTS

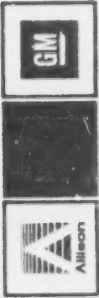


Figure 3. AGT 100 ceramic components.

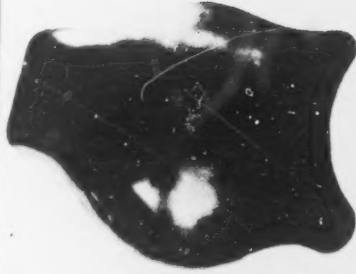
**PONTIAC PRODUCIBILITY EXPERIMENT
AGT 100 REGENERATOR COVER**



**CURRENT
ENGINE CONFIGURATION**



**EXPERIMENTAL
PRODUCIBILITY CONFIGURATION**



**WELDED ASSEMBLY OF
SEVERAL SEPARATE STAMPINGS**

**ONE PIECE STAMPING
SAE 4130 MATERIAL**

Figure 4. AGT 100 deep drawn sheet metal regenerator cover.



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- o accelerated engine testing and rig testing of components to turbine inlet temperatures in excess of 2000°F
- o methanol evaluation on the AGT 100 combustor
- o several iterations on design, processing and engine evaluation of ceramic components
- o demonstration of additional sheet metal shapes for the AGT 100 at Pontiac

Looking Ahead

Looking to the future, we are highly optimistic that our objectives, which were reviewed earlier, will be achieved within the next 2-1/2 years with funding remaining at the level of \$8.9 million per year. Figure 5 provides a detailed schedule of significant past and future events of the AGT 100 program.

The success of this program depends in large measure on continued favorable results of basic research in the exciting science of materials--specifically, high performance ceramics--and corresponding advancements in the ability to fabricate these new materials to extremely exacting tolerances.

The AGT 100 program represents much more than developing an engine concept. We and those associated with us are working at the leading edge of technology with new ceramic components needed to withstand temperatures that would deform some of the most costly and exotic metals we know of. Of equal importance, we are deeply involved in manufacturing research into practical methods of precision forming of component parts to withstand the high rotational speeds without distortion and fracture. In every respect, research in materials and their fabrication go hand in hand. Ultimately, any material substance is only as useful as our ability to form it consistently, reliably and economically.

While our ultimate program objective is related to a small lightweight gas turbine engine, what we are learning through our research will be applicable in other power plant configurations, including the diesel, rotary or Wankel

AGT 100 PROJECT SCHEDULE

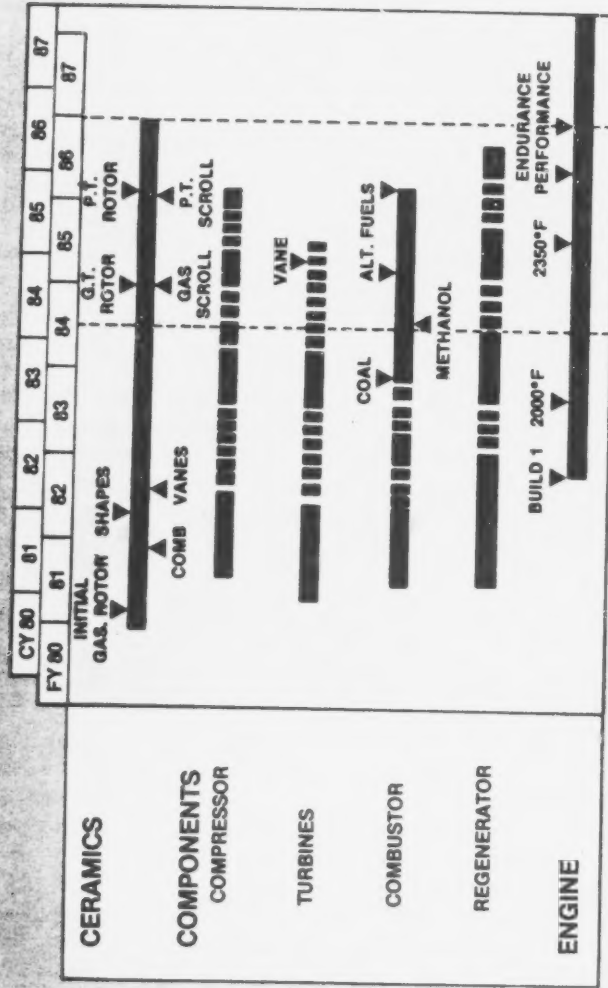


Figure 5. AGT 100 schedule.



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and the conventional gasoline engine. We also foresee many other uses where lightweight, high strength, precision fabricated components are required for use in high temperature environments.

With respect to the applications at hand--a small, high efficiency gas turbine--we are extremely optimistic about multi-fuel capability. In this era of heightened energy awareness, and recognizing that petroleum supplies are both finite and unsecure, we would be derelict if our research did not comprehend the use of alternate fuels. We have already demonstrated the gas turbine's capability to operate effectively on finely pulverized coal--an abundant U.S. energy source. Testing is also planned for later this year using methanol. Methanol is attracting widespread attention today because of its potential abundance, being a derivative of coal or natural gas.

Despite our justifiable optimism, we do not want to leave the impression that the research is complete or that the problems remaining are simply developmental in nature. Ceramic component development has not been achieved as quickly as originally planned. This is one of the risks that always accompanies research-oriented projects. Nevertheless, we urge no let-up in the effort now underway--there is light at the end of the tunnel.

One of our principal associates--GTE--in a letter which is attached to our statement puts this effort in proper focus. One short paragraph is especially significant:

"The market potential and embryonic state of these advanced ceramics is analogous to the situation with superalloys early in their development. In the superalloy case, specialty metal and engine manufacturing teams were funded by major national research, development and engineering programs. As a result of this concerted funding the U.S. still enjoys a dominant world position in the superalloy gas turbine engine market."

Most observers would agree that international competition for American products will intensify in the future. America is in an International race for



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technological superiority. To win that race demands a cooperative effort on the part of all segments of our society.

Government has a critical role, which is to support industry in high risk research that otherwise might not be undertaken--or perhaps not with the vigor that is required. We know, for example, that the Japanese government recognizes the potential that ceramic technology holds for lightweight, low cost, high performance power plants and several large Japanese companies have major programs underway using ceramic components.

General Motors looks forward to this Committee's continued support for the AGT 100 and other similar programs.

Thank you for this opportunity to review our progress on the GM-Allison project and to give you our views on the future of this exciting activity.


GTE Laboratories Incorporated

Paul E. Ritt
Vice President
Director of Research

40 Sylvan Road
Waltham, Massachusetts 02254
617 890-8460

February 8, 1984

Mr. H.E. Helms
Allison Gas Turbine Operations
General Motors Corporation
2001 South Tibbs Road
P.O. Box 420
Indianapolis, IN 46206-0420

Dear Gene:

GTE is a \$12 billion corporation involved in telecommunications, lighting and materials with a strong U.S. presence in research, development and supply of high performance silicon nitride components for advanced heat engines. Silicon nitride is one of a few ceramic materials which are critical to revolutionary designs such as the high temperature gas turbine or the adiabatic diesel both of which Allison has pioneered. These designs have been demonstrated with ceramic components but more development effort is necessary to meet production reliability requirements. The successful incorporation of ceramics in heat engines is a major undertaking comprising high risk, long payback and formidable competition from overseas, especially Japan.

The market potential and embryonic state of these advanced ceramics is analogous to the situation with superalloys early in their development. In the superalloy case specialty metal and engine manufacturing teams were funded by major national research, development and engineering programs. As a result of this concerted funding the U.S. still enjoys a dominant world position in the superalloy gas turbine engine market.

To duplicate this accomplishment with ceramics, advances are needed in the understanding of ceramic processing and production technologies. Additionally, ceramic base technology programs are required to develop the next generation of materials, for example ceramic matrix composites. These ceramic technology thrusts however, cannot stand alone. They must be fully integrated with advanced ceramic engine development programs. Engine programs provide brittle material design, application and engineering advancements. Moreover they specify actual components and real engine operating conditions against which the ceramic components can be iteratively developed and tested. Both pro-

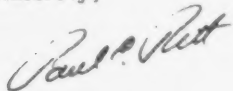
gram thrusts are required for marketplace success. They must be strongly interlinked, requiring iteration, feedback and good technical communication.

GTE has been teamed with Allison Gas Turbine Operations, General Motors since late in 1979. This partnership has encompassed both CATE and AGT programs with the focus of iteratively developing injection molding for the precision fabrication of complex sintered silicon nitride gas turbine engine components. Under DOE, NASA, GM and GTE funding, technologies to produce ceramic components with state-of-the-art mechanical and oxidation resistance properties have been developed. Progress in this project partnership continues with the focus of developing useful ceramic technologies which can be upscaled to produce parts which will operate successfully in real engines.

The CATE and AGT programs have maintained U.S. leadership in ceramic engines. The Japanese however, have targeted ceramics as a key technology for their future industrial growth and have established aggressive industry/government/university programs. They are worthy competitors and their progress is impressive.

Continued federal funding of engine and ceramic technology programs is critical. It defends a new generation automotive industry from offshore development of an "upstream" materials technology (ceramics) which would radically alter favored engine designs. Moreover these ceramic technologies have broad benefit to other applications with National significance, e.g. silicon nitride missile radomes or microelectronic components. Reduced funding would seriously risk staff-down of highly skilled R&D project teams which have taken years to assemble and train. This is not in the National best interest.

Sincerely,



DR. PAUL E. RITT
Vice President
Director of Research

Mr. GLICKMAN. We appreciate your being here today. Thank you. Our last witness today is Mr. Gerald H. Mader, Executive Vice President of the Electric Vehicle Development Corporation, Birmingham, Alabama.

**STATEMENT OF GERALD H. MADER, EXECUTIVE VICE
PRESIDENT, ELECTRIC VEHICLE DEVELOPMENT CORP.**

Mr. MADER. Mr. Chairman and members of the committee, I have prepared a summary statement. But I think in the interest of time I am just going to deliver three points to you that, in essence, capture what I try to say in the written testimony, and the written testimony then can be used by you as you wish.

Mr. GLICKMAN. Your entire statement will appear in the record.

Mr. MADER. Right.

The three points I would like to make are, No. 1, the Electric Vehicle Development Corp. is a newly established organization. It was created in November of 1983 to advance the development and marketing of electric vehicles. This organization currently has a membership of 30 utility companies that represent about 70 million consumers. We expect to have about 50 by the end of the year, plus other industry and business organizations.

My second point is the EVDC has two objectives. One is the commercialization of commercial fleet electric vehicles in the late 1980 timeframe, using near-term technology.

The second objective is commercialization of a passenger vehicle for the personal market sometime in the early 1990's.

My third point is that the Electric Vehicle Development Corp. strategy that it has adopted depends on other stakeholders to provide the needed technology; stakeholders meaning utilities, manufacturers, suppliers, and Government. Consequently, we feel that the Department of Energy can contribute to providing this technology by continuing to support lead-acid and nickel-iron battery development, electric van and truck propulsion system integration, advanced battery and powertrain R&D and technology testing through site operator user task force.

We believe that continued funding of the DOE program is needed for successful commercialization of the electric vehicle.

Those are my summary comments. I would be pleased to answer any questions you have on this organization or related to the technology.

Mr. GLICKMAN. So you believe that the Department of Energy is wrong for dropping its work on lead-acid and nickel-iron batteries?

Mr. MADER. Well, those technologies are not yet ready for commercialization. We need improvements in lead-acid technology, basically in the specific energy to improve the range in order to meet a commercial market. And we also need improvements in cost feasibility of nickel-iron technology and its energy efficiency.

Mr. GLICKMAN. What is the situation right now with regard to electric vehicle manufacturers in the United States?

Mr. MADER. Well, as far as organizations who are building electric vehicles for sale in the United States, there is only one organization that exists right now for that purpose, and that is Grumman

which is selling vehicles and which has sold vehicles primarily to the Post Office.

Mr. GLICKMAN. There's nobody else in the United States?

Mr. MADER. That's selling them commercially right now, no.

Mr. GLICKMAN. How about anybody who is doing—private companies doing research on the battery side of the picture?

Mr. MADER. Well, there are a number of organizations doing research, Ford Motor Co. There is some research being done by Chrysler. There is battery research being done by—in the lead-acid technology by Globe Union; nickel-iron batteries, Eagle-Picher. There's a lot of component development research being done.

Mr. GLICKMAN. Do you have any questions, Mr. Boehlert?

Mr. BOEHLERT. No, no questions, Mr. Chairman.

Mr. GLICKMAN. OK. We will read your full statement. We appreciate your being here very much.

Mr. MADER. Okay. Thank you.

Mr. GLICKMAN. I want to thank the witnesses for being so cooperative today. I am sure we will be in further touch with you.

On March 7 we will mark up at least our part of the Department of Energy bill. So in the next 10 days or 2 weeks, if anybody has any additional information they would like to share with the committee, they should contact the subcommittee staff.

The hearing is adjourned.

[Whereupon, at 11:18 a.m., the subcommittee was adjourned.]

[The prepared statement of Mr. Mader follows:]

STATEMENT OF GERALD H. MADER
EXECUTIVE VICE PRESIDENT
ELECTRIC VEHICLE DEVELOPMENT CORPORATION
to the
TRANSPORTATION, AVIATION AND MATERIALS SUBCOMMITTEE
OF THE HOUSE COMMITTEE ON SCIENCE AND TECHNOLOGY
HEARING ON
FY 1985 DEPARTMENT OF ENERGY & ENGINE R&D
PROGRAM BUDGET
February 22, 1984

Mister Chairman and Members of the Committee: My name is Gerald H. Mader, presently the manager of the Electric Transportation Program for the Electric Power Research Institute (EPRI). Today I am speaking on behalf of the Electric Vehicle Development Corporation (EVDC) where I will assume the position of Executive Vice President in March. On behalf of the EVDC, I would like to thank you for the opportunity to appear before this committee and report on the plans and activities of this new organization. This testimony is in response to your invitation of January 24, 1984 directed to Dr. William B. Harrison, Chairman of the Board, Electric Vehicle Development Corporation.

The EVDC is a nonprofit organization formed to advance the development and marketing of electric vehicles (EVs). EVDC was established in November 1983 to facilitate and accelerate the broad-based use of reliable, on-road electric cars and trucks in large numbers. The corporation's nucleus consists of 30 utilities which serve a collective population of over 70 million consumers. By the end of 1984, EVDC membership is expected to include more than 50 utility companies as well as business and industrial organizations with electric vehicle interests.

The EVDC has adopted a business strategy to accomplish two commercialization objectives. The initial commercialization objective is the development of an electric vehicle and support system for use within commercial fleets. This vehicle would utilize near-term battery and drivetrain technology. The demonstration of a market acceptable commercial EV would be conducted in the late 1980s. Introduction of EVs into the broader personal transportation market--the second commercialization objective--would be tied to the availability of advanced battery and drivetrain technology which can satisfy the more demanding performance requirements of that market segment. The timeframe for the introduction of an advanced EV is expected to be the early 1990s.

The EVDC has defined a generalized approach for introducing EVs. This approach involves the EVDC working with and through other EV stakeholders--utilities, manufacturers and suppliers, and government--to develop a market acceptable technology. The market introduction approach, which is designed to reduce technology and market risks, consists of six general steps which encompass a series of inter-related tasks and milestones. The steps are:

- o Define market applications
- o Assess vehicle and battery technology
- o Establish vehicle performance and design specifications
- o Develop/design prototype vehicles
- o Field test and define support system requirements
- o Conduct market-introduction demonstration

The EVDC will concentrate its efforts on characterizing the commercial fleet vehicle market and defining a vehicle specification which captures the largest market segment given the capabilities of near-term electric vehicle technology. In addition, the EVDC will create the technical and financial plans required to implement a large-scale demonstration as the initial stage in vehicle commercialization.

However, as the EVDC is neither an R&D organization nor a manufacturer, it must rely on others to supply the proven technology. It is for this reason that the cooperative and coordinated participation of the major EV stakeholders including the Department of Energy is required if the EV introduction strategy outlined above is to be successful.

Each stakeholder can make an important and unique contribution to the overall electric vehicle introduction strategy. The following describes the primary contributions each organization can make in working with the EVDC to accomplish EV commercialization.

- o Department of Energy:
 - Support lead-acid and nickel-iron battery development
 - Conduct dc powertrain development and testing
 - Support electric van and truck propulsion system integration
 - Continue technology assessment and review
 - Conduct advanced battery research and development

- Conduct ac powertrain development
- Support technology testing and evaluation through Site Operator User Task Force
- o Electric Power Research Institute:
 - Conduct in-vehicle evaluation and assist in development of near-term batteries which complement DOE development
 - Co-fund design, development and fabrication of test vehicles for use in integrated fleet vehicle systems
 - Test and evaluate prototype fleet EVs
 - Conduct advanced battery development to complement DOE development
- o Utilities and other major fleet operators:
 - Field test components and vehicles
 - Participate in introduction demonstration
 - Provide vehicle and component infrastructure support
 - Support information/technology transfer
- o Manufacturers:
 - Design and manufacture batteries and other vehicle components
 - Design and manufacture improved and advanced (fully integrated) vehicles which meet vehicle specifications
 - Provide vehicle and component service and support

Drawing these diverse organizations together represents a critical challenge; the fact that this had not been done previously was a major motivation behind the formation of the EVDC. The EVDC--that is, the corporation itself as well as its EV commercialization objectives--will provide the linkage or bond between these organizations. The EVDC recognizes the need for aggressively pursuing the establishment and maintenance of this linkage, and will encourage all stakeholder organizations to participate directly in the EVDC. The EVDC will also work to establish informal cooperative agreements with those organizations who are interested in the corporation's plans and objectives but who cannot participate as formal members.

The success of the EVDC is tied to the willingness of the various EV stakeholders to support their objectives and activities. To encourage this support, the EVDC's activities complement and build from the objectives and needs of each of these groups.

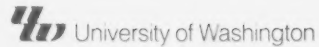
- o Utility Companies: EVDC provides an opportunity to participate in and influence the development of an end-use technology which is potentially a major new off-peak load and revenue source.
- o Vehicle and Component Manufacturers: EVDC's emphasis on defining and initiating a market for EVs should reduce a major source of uncertainty which has constrained investment in EV-related R&D.
- o Electric Power Research Institute: The EVDC will use EPRI's vehicle and battery test results to select the most applicable technologies for vehicle production; the EVDC commercialization objectives are also consistent with EPRI's Electric Transportation Program goals.
- o Department of Energy: The EVDC objectives are consistent with national policies to reduce the reliance on petroleum fuels and improve air quality; and directly utilize EV R&D programs sponsored by DOE by providing information on the market requirements for EV technologies, establishing a market for their technologies, and serving as a technology transfer agent.

With the enactment of Public Law 94-413, the Electric and Hybrid Vehicle Research, Development, and Demonstration Act, the DOE has been a major force behind the development of electric vehicles and related components in the United States. This effort continues to contribute to the technology and operating experience base from which a private sector initiated commercialization venture can be launched. Successful electric vehicle commercialization requires continued government funding for critical battery and powertrain research, development, and close cooperation between DOE, EPRI and the EVDC.

In summary, the formation of the EVDC comes at a critical crossroads in the development of EVs. Many promising advances in the technology have recently emerged which increase the feasibility of EVs as a viable transportation alternative. Uncertainty about the market for the technology, however, is restraining progress. The EVDC is in a unique position to provide the needed encouragement and direction for accelerating the introduction of EVs. However, EV introduction requires that further EV technology development be provided through the government's Department of Energy Electric and Hybrid Vehicle Program.

Thank you for the opportunity to present this statement.

APPENDIX



March 8, 1984

Honorable Dan Glickman
Chairman, Subcommittee on Transportation
Aviation and Materials
U. S. House of Representatives
Committee on Science and Technology
Suite 2321, Rayburn House Office Building
Washington, D. C. 20516

Dear Mr. Glickman:

May I again express appreciation for the opportunity on February 22nd to share with your committee the concerns and conclusions of the U. S. industry group involved with ceramics for heat engines. At the conclusion of my remarks you stated, "...the (DOD) guidelines place restrictions on revealing results of materials research. Those restrictions are thought unduly prohibitive, I think, by many in the private sector to the free exchange of information and results to maintain U.S. competitiveness...I wonder if you are familiar with those guidelines, if you would comment on them." Since that time, I have given additional thought to this question and would like to respond further with a few examples.

In January of each of the past eight years, the American Ceramic Society has held its Annual Conference on Composites and Advanced Materials at Cocoa Beach, Florida. When the "call for papers" was distributed to its world-wide membership last fall, several specific subject areas were defined including composites. For the past few years, due to Department of Defense policy, it has been necessary to separate most of the technical papers on the subjects of metal-matrix and ceramic matrix-composites, limiting these to U. S. citizens only. Due to the nature of our Society's tax-exempt status, it cannot hold meetings which have restricted attendance, so these papers are not considered a part of the Society's program but are sponsored by the DOD and NASA and scheduled for the two days following the American Ceramic Society's meeting.

Professor R. Naslain of the University of Bordeaux-I, France, submitted the titles of his papers which were included in the Society's program. Please note the attached, highlighted program. When the total program was published in the Society's Bulletin last November, he was obviously surprised and chagrined to learn that although all could hear the

Ceramic Engineering
and
Metallurgical Engineering

**Department of Materials
Science and Engineering**
Roberts Hall, FB-10
Seattle, Washington 98195
(206) 543-2600 543-2601

results of his research, he could not attend papers of prime interest because of his citizenship. After voicing his complaint to several of the program chairman and to the French Foreign Office, he withdrew both papers. You may note from the titles of other papers in the "U. S. Citizens Only" program, attached, that considerable similarity in subject matter may have existed.

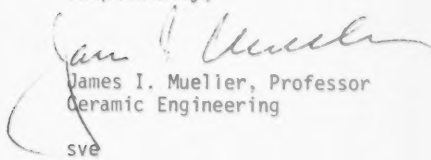
It is recognized that this is an isolated case, but it is one which represents the possibility of a substantial reduction of international information exchange. I am also sympathetic to the desire of keeping strategic technology from leaking to unfriendly countries, but the determination as to what research reports should be open or for U.S. eyes and ears only is too often left to agency contract monitors with tendencies to be ultra-conservative in their grading.

During Dr. Kapper's discussion of the policy draft document in 1983, I raised the question as to how this might affect academia. Specifically, if I was supervising research on ceramic matrix composites which might lead to an understanding of processing methods to vastly improve the characteristics of those composites, those results could be considered for "U.S. citizens only." We are all too well aware of the large percentage of foreign graduate students in engineering and the sciences. I pointed out that I could not and would not be able to exclude non-citizens from a departmental seminar in which my student described this work. By necessity, therefore, I would not undertake any future work under grant or contract which could result in such a situation. With hundreds of other faculty members under similar constraints, I question which nation would soon suffer from a dearth of information on these subjects.

Unlike the situation 20-25 years ago, we are not longer the prime source of science and technology and those of us who have traveled to visit and meet with our international colleagues have indeed learned considerable from them in the past few years. Their willingness to participate in the exchange of scientific and technical information in my field is evidenced by the large number of foreign nationals who present meaningful papers at the Annual Meetings of the American Ceramic Society and who publish in its Journal. The attached tables attest to this.

Again may I thank you for the opportunity to express my views on these matters of importance.

Respectfully,



James I. Mueller, Professor
Ceramic Engineering

sve

Enclosures

Nationality of Principal Authors
Presenting Papers at the Past Four
Annual Meetings of the
American Ceramic Society

<u>Year</u> (Location)	<u>United States</u>	<u>Foreign</u>	<u>Total</u>
1980 (Chicago)	721	122	743
1981 (Wash. D.C.)	720	121	780
1982 (Cincinnati)	763	117	780
1983 (Chicago)	737	154	891

Nationality of Principal Authors
Presenting Papers at the
Annual Meeting of the American Ceramic Society
Chicago, Illinois, April, 1983

<u>Country</u>	<u>Numbers of Papers</u>
United States	729
Japan	28
Canada	26
Federal Republic of Germany	26
France	15
Brazil	12
United Kingdom	11
Spain	5
Egypt and Sweden	4 each
Chile, India, Peoples Republic of China, South Africa, Yugoslavia	3 each
Australia, Italy, Nigeria, Poland, S. Korea	2 each
Belgium, Czechoslovakia, Finland, Mexico Netherlands, Switzerland	1 each
TOTAL	891

(Note: Nationalities evaluated by different person than in previous table.)

Nationality of Principal Authors
Publishing Papers in the
Journal of the American Ceramic Society
Volume 66, 1983

<u>Country</u>	<u>Number of Papers</u>
United States	130
Japan	23
Federal Republic of Germany	6
Republic of South Africa	4
Australia, France, India, United Kingdom	3 each
Canada, Egypt, Greece	2 each
Denmark, Finland, German Democratic Republic, Peoples Republic of China, Hungary, Spain, Yugoslavia	1 each
TOTAL	188

CABLE UAW DETROIT

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February 13, 1984

FEB 16 1984

Congressman Dan Glickman, Chairman
Subcommittee on Transportation, Aviation and Materials
House Committee on Science and Technology
2321 Rayburn House Office Building
Washington, D.C. 20515

Dear Mr. Chairman:

The UAW is submitting this letter for the record of your Subcommittee's hearings on the U.S. Department of Energy's transportation program and its FY 1985 funding. We appreciate your invitation to do so again this year.

As we testified before your Subcommittee in July 1981, and as we wrote you in February 1982 and again last February, we strongly believe that there needs to be much more, not less, government-sponsored automotive R&D. The decline in petroleum product prices since 1981, we fear, is creating within the industry a sense of false security with regard to the kind of vehicles that will be in demand in the years and decades ahead.

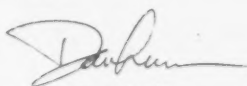
Much has been written about the supposed role of outsourcing — of both vehicles and engines/transaxles — in reducing the domestic OEMs' costs and hence improving their competitiveness. The reality, however, is that through outsourcing and a deemphasis on new engine R&D, the U.S. is losing not only jobs but technological experience. With the U.S.-based producers showing growing signs of abandoning interest in domestic production of state-of-the-art small vehicles and their components, a government decision to abandon support for new, fuel-efficient engine R&D could well mean that when the next fuel shock hits, this country will no longer be competent to supply the products demanded by consumers in our home market.

Regardless of the decisions made in U.S. auto company board rooms, we insist, as we did last year, that the nation has a large stake in seeing that the commercialization of U.S.-generated automotive technology occurs in this country. Sadly, the Administration's proposed DOE transportation budget proposals illustrate once again its continuing failure to grasp this. Believing that only a passive, penny-wise and pound-foolish government is consistent with the "free market," it proposes to slash U.S. Stirling and gas turbine work, and to ignore the serious need to develop ceramic applications in diesel power plants.

This could be a disaster. In the case of Stirling work, it would pull the plug on research that reportedly is close to proving out an efficient, multiple fuel-compatible, clean, quiet power plant that could replace many of the imported engines used in and planned for domestically-assembled cars and light trucks. In particular, the MOD II -- if brought to commercialization in the 1985-88 time frame -- can leapfrog Japan in heat engines, despite their far better-funded Stirling program. Cutting U.S. Stirling, gas turbine, and adiabatic diesel contract work would send MITI the message that the U.S. has decided to cede the next generation of heat engines to Japan.

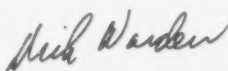
If the U.S. wants a competitive auto industry, we must decide to have one. A key element in that decision is government-funded power plant R&D. Despite meager past federal support, there are signs that spending is about to bear fruit. At a time when every other significant industrial country is nurturing high-risk research investments in the new engine (and especially ceramics) field, it would be the height of ignorance and arrogance for the United States to risk our auto industry's future in blind homage to free market ideology.

Again, our thanks for providing the UAW this opportunity for comment on the FY 1985 transportation program.



Dan Luria
Research Economist

Sincerely,



Dick Warden
Legislative Director